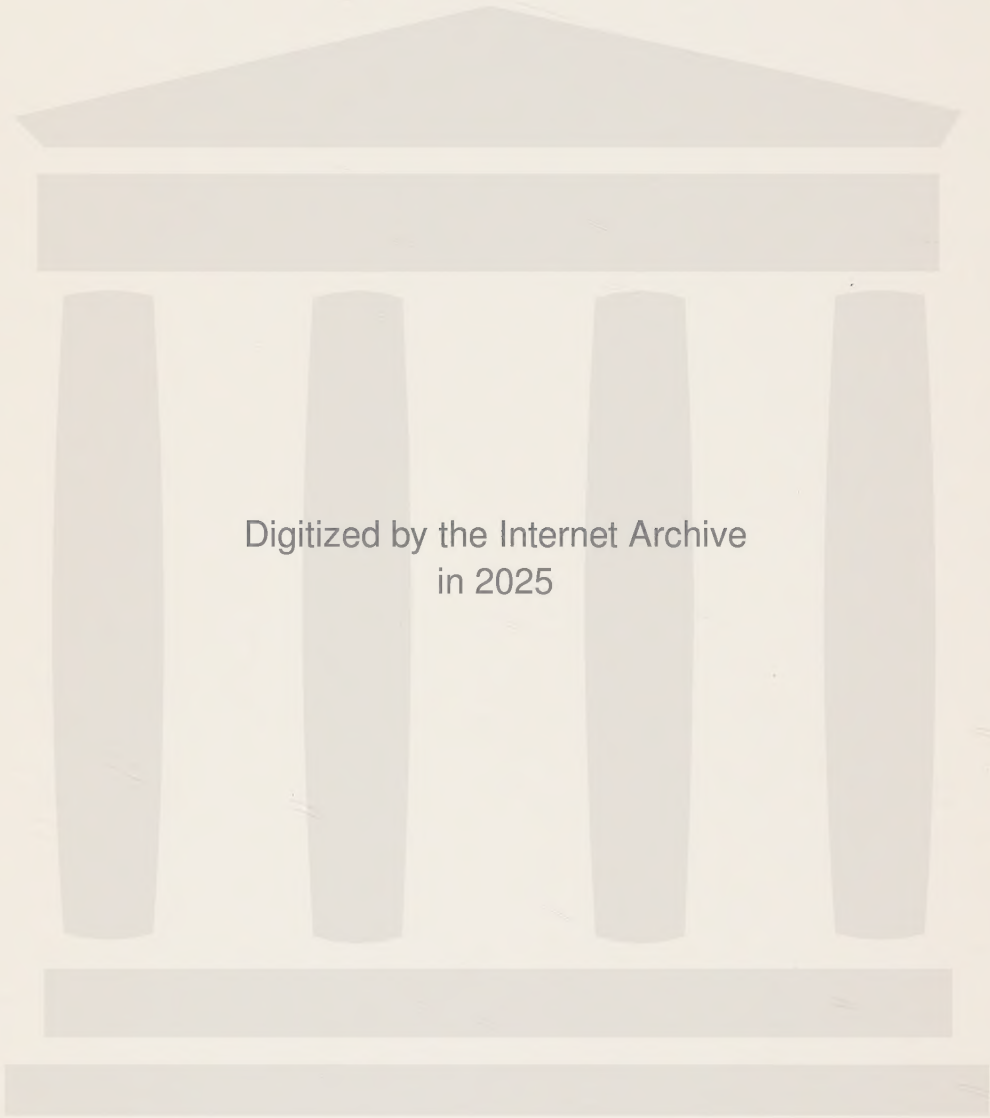
1960 REPORT

Experiment Station

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

COMMONWEALTH MYCOLOGICAL INSTITUTE
22 FEB 1961



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THE EXPERIMENT STATION

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

REPORT

October 1, 1959 to September 30, 1960

LETTER FROM THE DIRECTOR 1
CULTURAL PRACTICES 3
DISEASES 22
EXPERIMENTAL STATISTICS 28
FACTORY 29
INSECT AND RAT CONTROL 34
IRRIGATION 38
MECHANIZATION 48
TILLAGE 61
VARIETIES 66
WEED CONTROL 70
PERSONNEL TRAINING 80
EXPERIMENT STATION STAFF 83
STATION PERSONNEL CHANGES 85

On the Cover:
Experiment Station, 1960
(taken from new Keeaumoku Street overpass)

During the year, Dr. Roger P. Humbert, Head of the Agronomy Department, resigned and he was succeeded by Dr. George Stanford, who has come to us from the Tennessee Valley Authority. Mrs. Lydia Nickerson retired as Associate Editor and her position has been filled by Mrs. Edith Haselwood, who comes to us from the Department of Oceanography, University of Washington.

You will be interested to know that our Library now contains 73,209 volumes of catalogued material; these include subjects on agriculture, sugar cane cultivation and technology, chemistry, biology, botany, pathology and engineering. Our scientific collection has been increased by 1,143 new books and 13 microfilms and photoprints.

Staff changes are listed on page 85.

Respectfully submitted,

L D Baver

Director

CULTURAL PRACTICES

NUTRIENT STATUS OF SOIL AND PLANT STUDIED

Twenty-two fertilizer experiments were selected for detailed studies on crop logging, although samples were included from 49 experiments during the year. The 8–10 stalk samples were analyzed for N, P, K, total sugars, reducing sugars, and, in certain instances, for Ca and Mg. Soil samples taken from Grade A experiments before fertilization also were analyzed for extractable nutrients. Relations of plant and soil analyses to crop responses generally confirmed previous evidence as to levels of nutrient deficiency or sufficiency in soil and plant. No responses to Mg application were obtained in six field experiments where soil-exchangeable Mg ranged from 35 to 55 pounds per acre-foot; evidently the critical level of soil Mg will prove to be very low.

CANE RESPONDS TO SULFUR IN POT TESTS

Sulfate-sulfur content of Hawaiian soils ranges from almost nil to several thousand ppm S. In view of the trend toward decreasing S content of applied fertilizers, studies on the S status of important sugar cane soils have been emphasized. In pot tests with low-sulfate Makiki, Ewa, and Lihue soils (less than 40 ppm extractable S), marked responses to applied gypsum ($CaSO_4$) occurred. With Makiki and Ewa soils, responses were apparent three months after planting, while with Lihue soil, S deficiency and growth response were not evident until nine months; Figure 1 shows differences due to S at 13 months.

It is important to note that pots were irrigated with S-free water. Pump irrigation waters may contain large amounts of S (e.g., 100 to 500 pounds per million gallons), while surface mountain waters usually contain small amounts. This factor must be considered in relation to S fertilization.

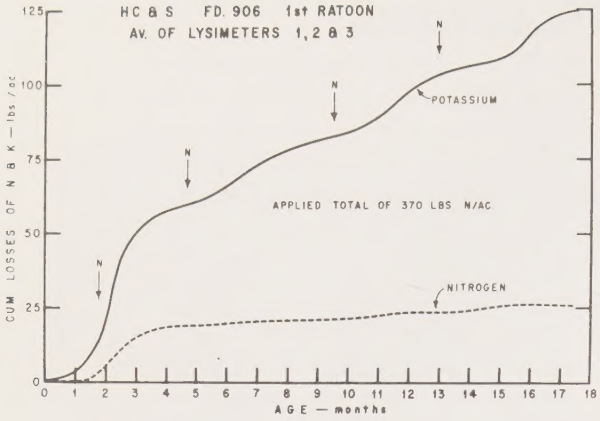
HC&S LYSIMETERS SHOW LEACHING LOSSES

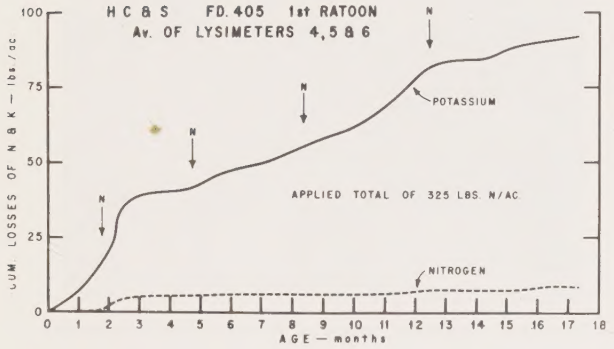
As shown in the 1958 Annual Report, average N and K losses under the plant crop from three field-installed lysimeters (Field 906) were 150 and 155 pounds per acre, respectively. Under the first ratoon crop (years 1959–1960), average loss of K

Figure 1. Sulfate applied as gypsum increased cane growth on Lihue soil. Irrigation water was S-free.

from these same lysimeters was 125 pounds per acre, or 80 per cent of that from the first crop; however, N loss was only slightly more than 25 pounds per acre, or 16 per cent of that from the plant crop. Approximately 350 pounds N per acre were applied during each cropping period. Neither crop was fertilized with K.

Similarly, in Fields 405 and 205, average leaching losses of N were considerably lower than of K under the first ratoon crop. This result may be associated with the immobilization of N during decomposition of root residues from the plant crop. Reasons for the large difference in N loss between plant and first ratoon crops, exemplified by Field 906 lysimeter data, should be investigated in view of its practical significance. Data are shown in Figure 2.





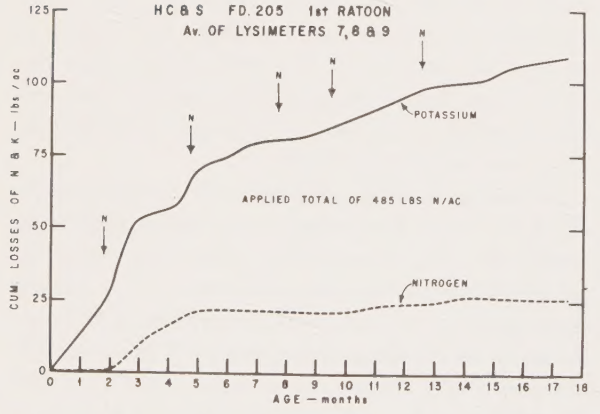


Figure 2. Leaching losses of N were much less than of K from lysimeters under the first ratoon crop.

EFFECTS OF LIMING ARE DIVERSE

Reasons for growth and yield responses from liming acid soils often are not clearly evident since this practice induces various chemical and biological effects in soil as well as physiological effects in the plant.

Seven field experiments harvested in 1960 included varying levels of liming. In five of these tests, both sugar and cane yields tended to increase with rates of lime. Table 1 shows one test in which sugar yields were increased significantly by each increment of lime applied.

Factors contributing to the beneficial effect of liming are being explored. The curves in Figure 3 indicate that the rate of mineralization of organic N is enhanced by liming. With this acid hydrol humic latosol, pH values four months after liming were 4.9, 5.5, 5.9, and 6.4 for 0, 5, 10, and 20 tons limestone per acre; a marked upsurge in microbial activity associated with N release occurred when soil pH exceeded 6.0. In this laboratory experiment, lime was thoroughly mixed with soil whereas, under field conditions, lime is heterogeneously distributed in "pockets". Thus, effects associated with liming are expected to vary markedly from one point to another in the soil mass.

Amounts of soluble aluminum (Al) increase as soils become more acid. It is not clear whether reduced crop growth on acid soils is due to an overabundance of active or soluble Al, to low exchangeable Ca, or to other factors. However, liming reduces the amounts of Al extracted by an acidic (pH 4.8) solution of ammonium acetate (Table 2). Although reductions in extractable Al clearly were brought about by liming, Al solubility remained relatively high even with limestone applications extending well above the level required normally to achieve optimum yield responses.

Table 1. Liming Increased TCA and TPA on Hilo Soil (pH 4.6) of Pepeekeo Sugar Co. Plant Crop Harvested at 26 Months

Lbs. CaO/A	TCA	TPA
0*	83.9	9.2
1120	106.7	10.7
2240	108.3	11.5
LSD	7.5	0.8

*Unlimed soil contained 98 pounds exchangeable calcium per acre, which represents a severe deficiency of this nutrient.

Table 2

Soil	Limestone	Extractable* Aluminum	Soil	Limestone	Extractable** Aluminum
	Tons/A	ppm		Tons/A	ppm
Onomea	0	2,060	Laupahoehoe	0	3,190
Onomea	4	1,800	Laupahoehoe	5	2,880
Onomea	8	1,580	Laupahoehoe	10	2,410
Onomea	16	1,510	Laupahoehoe	20	2,100

*3 months after liming.

**4 months after liming.

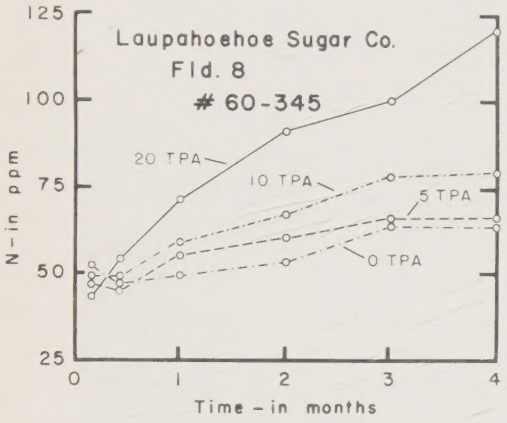


Figure 3. Liming an acid hydrol humic latosol increased mineralization of organic nitrogen.

POTASSIUM LEACHING RELATED TO CALCIUM STATUS OF SOILS

In addition to its role in correcting soil acidity, liming offers a means of conserving applied potassium fertilizer. Reduction in leaching losses of K by liming is illustrated in Figure 4. The effect was most pronounced with the 6-ton limestone application and diminished with succeeding increments. Similar results were found with two other hydrol humic latosols. Limestone was well mixed with the soil contained in leaching columns. Whether localized placement of limestone along with the KCl in the line will be effective in retarding K leaching merits study.

Variations in the exchangeable Ca level of four Kohala soils also were inversely related to K lost by leaching (Table 3). Retention of applied K by soils from the Upolu fields was high despite the natural occurrence of excessive quantities of exchangeable K.

Figure 4. K leaching was reduced by lime thoroughly mixed in soil columns.

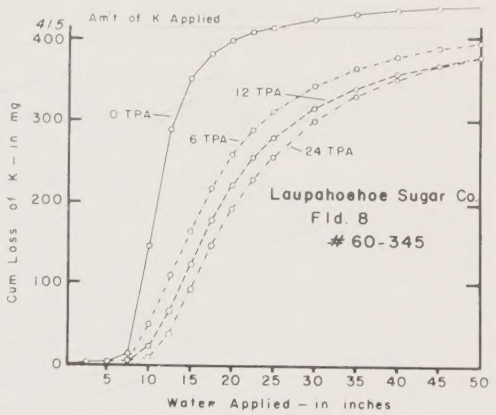


Table 3

Field	Great Soil Group	pH	Calcium	Applied Potassium Lost
			lbs./A	% of Total
Upolu 4	Low humic latosol	6.0	4,625	7
Upolu 20	Low humic latosol	6.2	4,300	11
Iole 6	Humic latosol	4.8	1,175	40
Niulii 26	Humic latosol	5.2	500	66

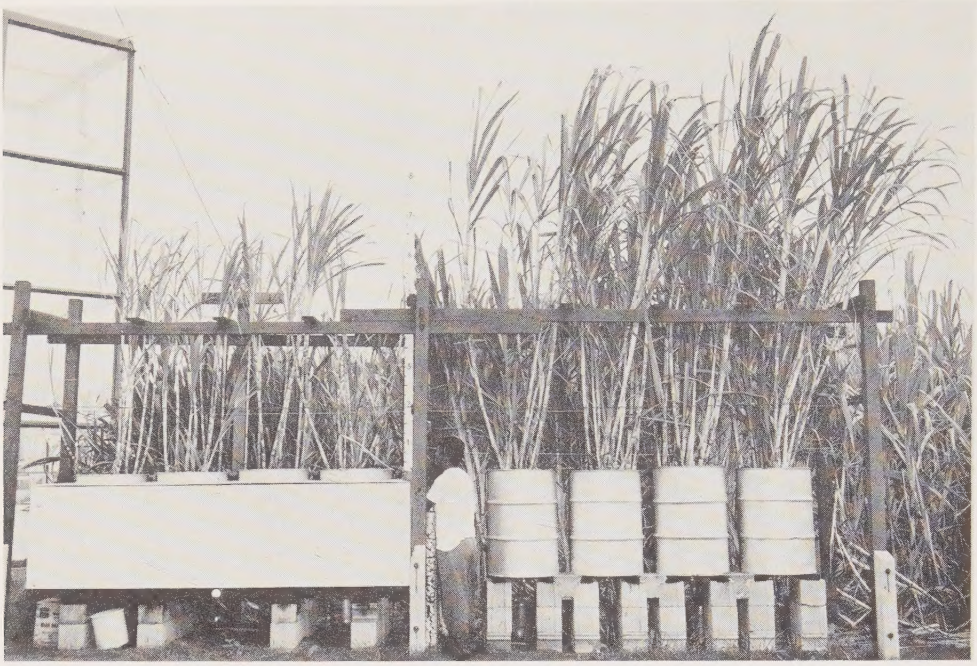


Figure 5. Low soil temperature, 62°F., (four pots on left) sharply reduced growth of cane and increased N and K leaching as compared to plants grown at normal air temperautre (four pots on right).

SOIL TEMPERATURE AFFECTS LEACHING LOSSES

Cane plants were grown for three months on hydrol humic and humic ferruginous latosols contained in large steel lysimeters, after which comparable cultures were subjected to different soil-root temperatures, 62° F. and the prevailing ambient temperature. On the cooled pots, impairment of growth soon was evident. At the age of eight months, a large growth differential existed (Figure 5). Pots were fertilized with N and K salts, irrigated with ion-exchange water, and leachates were collected at weekly intervals.

Under vigorously growing cane at Makiki temperature, losses of applied N and K were small and occasionally negligible. Cooling the pots increased N losses threefold from Lihue soil (humic ferruginous) and 20-fold from Onomea soil (hydrol humic). Although K losses from Lihue soil possessing high K-retentive capacity were relatively small at either temperature, leaching was somewhat greater from cooled pots. K losses from Onomea soil of low K-retentive capacity also were low at Makiki temperature, but were increased 40 times by cooling.

Two factors might account for higher losses of nutrients by leaching associated with lower temperature: (1) lower capacity of plants to take up nutrients because of restricted root and top growth, and (2) temperature-induced reduction in physiological availability of N and K. Implications of these preliminary findings in connection with fertilizing for increased sugar production during the cooler months, particularly in high-rainfall mauka areas, are worthy of consideration.

GROWTH AND YIELD RESPONSES TO NUTRIENT ELEMENTS

During the past year further studies of the American Factors data have led to statistical correlations between analytical values in plant parts and between these and available soil nutrients. Some of these are presented in Table 4.

These correlations serve as an indicator of usefulness of various tissue and soil analyses in foliar diagnosis.

Table 4

Correlation Coefficient Between Plant Parts and Plant and Soil Composition.*

Quantities Compared	Correlation Coefficient
1. Alcohol-soluble basal N vs. basal total N	=0.99
2. Basal total N vs. 8–10 total N	=0.94
3. 8–10 N vs. leaf N	=0.84
4. 8–10 N vs. 8–10 moisture	=0.81
5. Leaf N vs. sheath moisture	=0.63
6. 8–10 N vs. 8–10 reducing sugars	=0.84
7. Basal K vs. 8–10 K	=0.73
8. 8–10 K vs. sheath K	=0.92
9. 8–10 K vs. available soil K	=0.95
10. Sheath K vs. available soil K	=0.91
11. 8–10 K vs. 8–10 moisture	=0.15
12. Sheath K vs. sheath moisture	=0.28
13. Basal P vs. 8–10 P	=0.70
14. 8–10 P vs. sheath P	=0.17
15. 8–10 P vs. available soil P	=0.44
16. Sheath P vs. available soil P	=0.07
17. 8–10 M vs. sucrose-reducing sugar ratio	=0.94

*Data from group test No. 11 (AMFAC). All fertilizer applied early.

SOIL TEMPERATURE INFLUENCES EARLY GROWTH

The adverse effect of cool soil on the germination and growth of sugar cane was shown by an experiment installed at an elevation of 1,350 feet in a field of the Hilo Sugar Company.

Three adjoining lines, 30 feet in length, were heated by electric soil-heating cable. The cables were placed at 5 and 12 inches below the surface and the controlling thermostats were set for a maximum temperature of 85° F. The temperature of the unheated soil ranged from 65° F. near the surface to 67° F. at 30 inches.

Half of each of the heated and unheated lines were treated with methyl bromide at the rate of 2 pounds per 100 square feet. The plot was planted to variety 44–3098 on February 15, 1960. At 2½ months, the treated rows had 2.5 times more stalks than the check rows, the other two treatments falling between these extremes. At 8 months all treatments and the check rows reached the same stalk population, due largely to death of stalks in the densely populated areas.

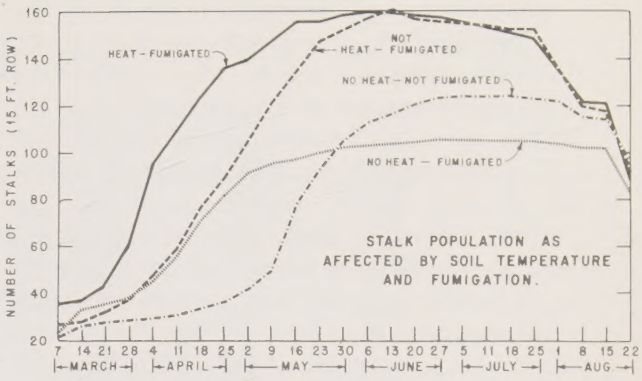


Figure 6.

Figure 6 shows the rate of shoot formation and the subsequent mortality.

JUICE QUALITY RELATED TO MOISTURE STRESS

The effect of drying-off in improving quality of juice is known to depend on decreasing water content, increasing sucrose, and decreasing reducing sugars, with higher ratio of sucrose to reducing sugars. But drying-off is also known to decrease the new formation of sugar by photosynthesis in the leaf. To obtain maximum benefits from drying-off, a balance must be struck between good effects and bad effects in such a way as to increase yield of tons sucrose per acre.

Plants which had been grown in uniform control solutions were transferred to solutions containing sodium chloride (C.P.) in amounts to give 0.4, 4.4, and 6.4 atmospheres pressure, including the complete nutrient solution. After only two days, changes were found in sugar content (Table 5) showing improved sucrose/reducing-sugar ratios with higher pressure of nutrient solution.

Table 5. Sugars and Moisture of Internode 12 After Only 2 Days in Experimental Solutions

Atmos. press. of nut. soln.	Moisture %	Red. sugars % dry wt.	Sucrose % dry wt.	Sucrose/reducing sugars ratio
0.4	81.7	1.87	32.99	17.6
4.4	81.3	0.89	43.71	49.1
6.4	79.0	0.73	35.98	49.3

Juice ripening was also studied in mature plants, each having several suckers and considerable millable cane. Moisture supply was regulated by adjusting the pressure of nutrient solutions by the addition of sodium chloride, giving 0.4, 2.4, and 4.4 atmospheres pressure. Measurement of utilization of water showed no difference at first, but after three days the plants with 4.4 atmospheres pressure absorbed less water than the others. Six plants harvested at one week gave no differences in moisture per cent or juice analyses. Six replicate plants were continued a second week at pressures of 0.4, 2.4, and 4.4; then the 2.4 and 4.4 were changed to 6.4, and continued two more weeks. The 6.4 plants absorbed noticeably less water than the 0.4 plants. At four weeks the plants were harvested. Results for moisture and sugars in 8–10 internodes (Figure 7) showed definite ripening associated with lower moisture.

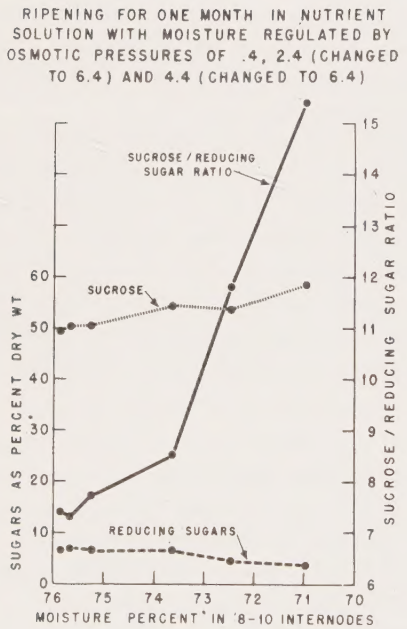


Figure 7.

VARIETIES DIFFER IN RESPONSE TO NITROGEN

Studies in 1959 demonstrated that one of the more striking differences between 10 well-known varieties is the response to levels of nitrogen fertilization. Varieties may be grouped as (1) nitrogen-sensitive, (2) intermediate, and (3) nitrogen-insensitive. Heavy applications of nitrogen fertilizer have a small effect on the juice quality of the first group and a large effect on the third group.

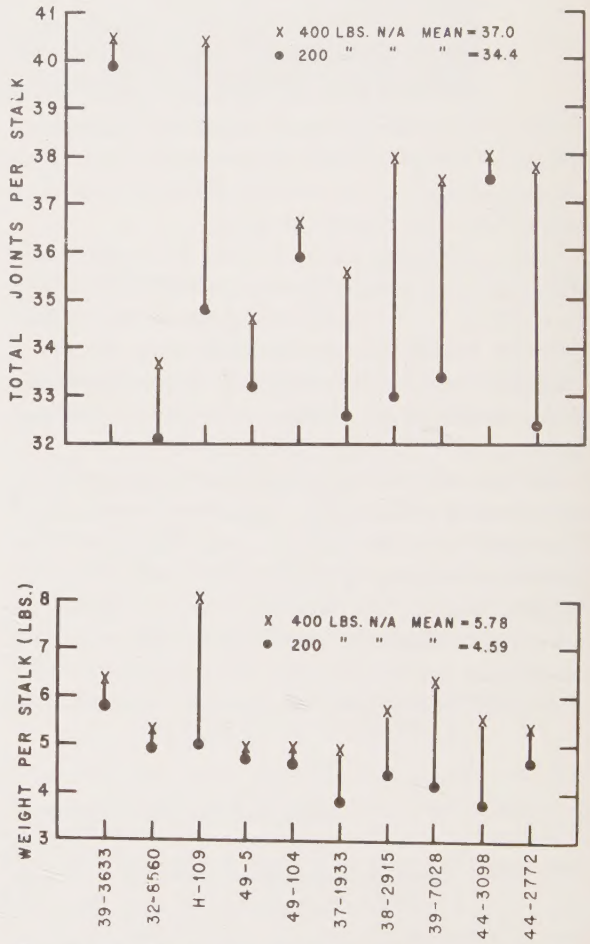


Figure 8. Comparative joint and plant weight of ten varieties (12 months).

Table 6. Varietal Differences in Pol, K and P Compositions

Varieties	Group	Pol % Cane 200 lbs. N	Pol % Cane 400 lbs. N	% K in 8–10 200 lbs. N	% K in 8–10 400 lbs. N	% P in 8–10 200 lbs. N	% P in 8–10 400 lbs. N
6 Months							
49–5	1	7.49	5.92	2.13	1.62	0.171	0.194
49–104	1	8.35	5.98	1.90	1.82	0.193	0.205
37–1933	1	8.03	5.84	1.04	1.16	0.114	0.126
32–8560	1	6.58	5.99	1.44	0.97	0.170	0.175
38–2915	2	3.26	3.91	1.81	2.91	0.231	0.242
39–7028	2	4.70	4.32	1.90	1.94	0.209	0.231
44–2772	2	3.74	3.92	1.49	2.39	0.204	0.224
H–109	3	5.79	3.92	1.69	0.61	0.234	0.178
39–3633	4	6.09	6.45	1.01	1.07	0.137	0.118
44–3098	4	5.77	6.77	1.52	3.22	0.183	0.142
9 Months							
49–5	1	14.59	12.40	1.42	1.04	0.168	0.125
49–104	1	12.32	11.96	1.47	1.51	0.112	0.135
37–1933	1	12.48	11.92	1.05	1.06	0.141	0.107
32–8560	1	13.94	12.48	1.16	1.02	0.121	0.130
38–2915	2	9.73	9.24	1.08	1.85	0.098	0.149
39–7028	2	9.78	8.47	1.45	2.16	0.132	0.158
44–2772	2	10.23	9.25	0.89	1.95	0.153	0.178
H–109	3	8.85	5.54	1.58	1.46	0.168	0.204
39–3633	4	11.86	8.82	1.07	1.57	0.112	0.120
44–3098	4	10.23	9.89	1.22	1.52	0.143	0.125

Table 6 shows tnat at nine months the members of Group 1 have high pol per cent cane and low P and K, with high nitrogen fertilization. Additional N tends to lower or leave unchanged the P and K values. Group 2 has lower pol values and additional N greatly enhances the P and K values. H–109 is put in a class by itself because of the very large effect of high N on pol. Group 4 is separated from the others because of its special analytical values.

In another study of these 10 varieties made this past year on the ratoon crop, the rates of node formation and the stalk sizes were compared (Figure 8). The varieties have not been regrouped but are listed according to their location in the field. It is immediately apparent that all varieties add joints at approximately the same rate (± 10 per cent of the mean) and produce stalks of approximately the same size (± 20 per cent of the mean). The following conclusions may be drawn from these data:

1. In every case the extra nitrogen increased both the number of joints and the weight of the stalk.

2. The effect of extra nitrogen varies greatly with variety.

3. In many cases there is a good correlation between the growth effects shown in Figure 8 and the composition effects shown in Table 6.

As a working hypothesis, the data in Figure 8 might be summarized as follows: some varieties (39–3633, 32–8560, 49–5, 49–104) approach maximum yield with 200 pounds nitrogen per acre. Others (H–109, 37–1933, 38–2915, 39–7028, 44–3098 and 44–2772) benefit greatly from nitrogen addition above 200 pounds nitrogen per acre. Especially striking in the latter group are H–109, 38–2915 and 39–7028.

Since the extra nitrogen also lowers the pol per cent cane, it is clear that to benefit from the additional storage space in the larger stalks adequate time must be allowed for the cane to ripen with stored sucrose.

SINGLE-EYE PLANTINGS POINT OUT GROWTH CHARACTERISTICS OF VARIETIES

Under the usual planting practice, several primary stalks per foot are not uncommon. As the secondaries multiply, competition becomes so keen

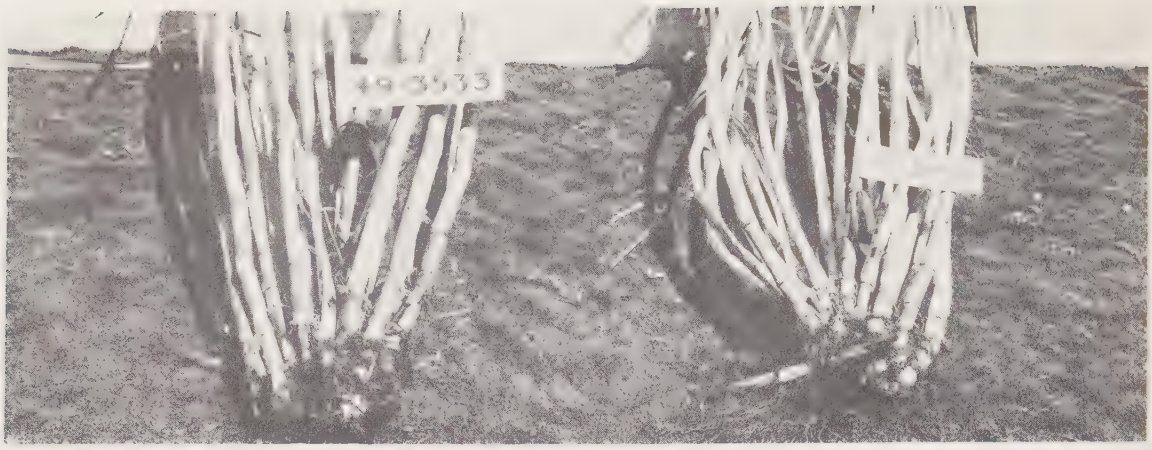


Figure 9. Massive stalks from single-eye plantings.

that the potential development of each stool is never realized. This effect is still more pronounced in the ratoon crop with the result that the final stand consists of many small stalks, badly crowded.

In order to compare stool growth of some varieties under non-competitive conditions, newly plowed plots at Makiki were fumigated and planted with single-eye seed pieces 5 feet apart in 5-foot lines. These were staggered to give maximum distance between stools. The six varieties chosen for this study were the two occupying the largest acreage in the state, 37–1933 and 44–3098, and four relative newcomers being spread in new plantings at a rapid rate, 49–5, 44–2772, 50–7209 and 49–3533.

There are two plots of each variety, each plot containing 24 stools. Each stool was fertilized with ammonium sulfate as a unit, the fertilizer being leached into the ground before furrow irrigation had the chance to wash it away.

The growth potential of single eyes is illustrated in Table 7. With 20 to 30 stalks per stool and a stool every 5 feet, the average per foot of line is 4 to 6, a good stand. Within 3½ months after planting, the leaf canopy appeared about as complete as one obtained at that age from the usual multiple seed planting. Furthermore, the stalks produced are of the massive type shown in Figure 9. By chance each of these stools had 23 stalks and each stool was 12 to 13 feet high at time of harvest (9 months).

Total millable cane (joint No. 8 to base) was 122 pounds for 49–3533 and 116 pounds for 37–1933. Converting to an acreage basis these varieties had, nine months after planting single eyes, produced 100 tons of clean cane per acre.

Table 7. Average Stalk Population in Stools of Six Varieties Planted as Single-eye Seed Pieces. Age 7½ Months

Variety	Plant No.	Stalks per Stool
50–7209	1	18
50–7209	7	20
49–3533	2	16
49–3533	8	18
49–5	3	26
49–5	9	22
44–3098	4	36
44–3098	10	35
44–2772	5	27
44–2772	11	30
37–1933	6	28
37–1933	12	27

Ca45 DEMONSTRATES Ca REUSE

Calcium, a relatively immobile element in the plant compared with potassium or phosphorus, is reutilized to a certain extent in the leaves of sugar cane. A plant was fed one millicurie of Ca45 on July 31. Five days later the radioactive solution was replaced with non-radioactive solution. Leaves of this plant were punched October 5 and the same leaves were punched again on the

opposite side on November 2. Counts of these punches are presented in Table 8. The older blades (Nos. 11 to 13 on October 5) lost calcium counts by November 2, whereas the younger blades (Nos. 2 to 10 on October 5) gained calcium counts, which indicates reutilization of calcium.

Table 8. Total Counts in 6 Leaf Punches of Plant Fed Ca45 (corrected for decay)

No. of blade	Counts in 6 punches		No. of blade
October 5	October 5	November 2	November 2
	—	59	1
	—	91	2
	—	78	3
2	60	130	4
3	122	187	5
4	171	277	6
5	339	432	7
6	392	475	8
7	574	644	9
8	818	978	10
9	956	1,082	11
10	817	1,001	12
11	1,221	1,182	13
12	1,109	1,062	14
13	1,535	1,030	15

Ca45 fed to a leaf in the dewlap region entered the leaf and moved to all parts of that stalk and also to another stalk of the same plant. Nodes tended to have more calcium counts than internodes.

The gradual gain in calcium by older leaves is often interpreted as meaning that no calcium is leaving in the general circulation. The present experiment demonstrates that, although there is a net gain in calcium with age, there is an outflow of appreciable size.

HEAVY NITROGEN, N15, USED IN AQUA AMMONIA STUDIES

Methods of application with regard to efficiency of utilization of ammonia fertilizer when applied (a) in irrigation water on the cane line and (b) by injection of aqua ammonia 19½ inches on each side of the center of the furrows were studied at Waialua Agricultural Company, using N15. Plantation practice for these procedures was followed as closely as possible. The experimental plots and treatments are shown in Figure 10.

The results, although somewhat unexpected, were very consistent throughout the tests. Figure 11 shows the per cent N15 in leaf punches following the application on the ratoon. N15 content is a direct measure of the amount of fertilizer nitrogen taken up without regard to quantity of soil-available nitrogen. (*Injected fertilizer was taken up much more readily than that applied over the stools in irrigation water.*) The differences are measurable at the 50-pound level and are very striking at the higher level. The results of this ready uptake of injected ammonia are reflected in all other measurements made throughout the one-year crop.

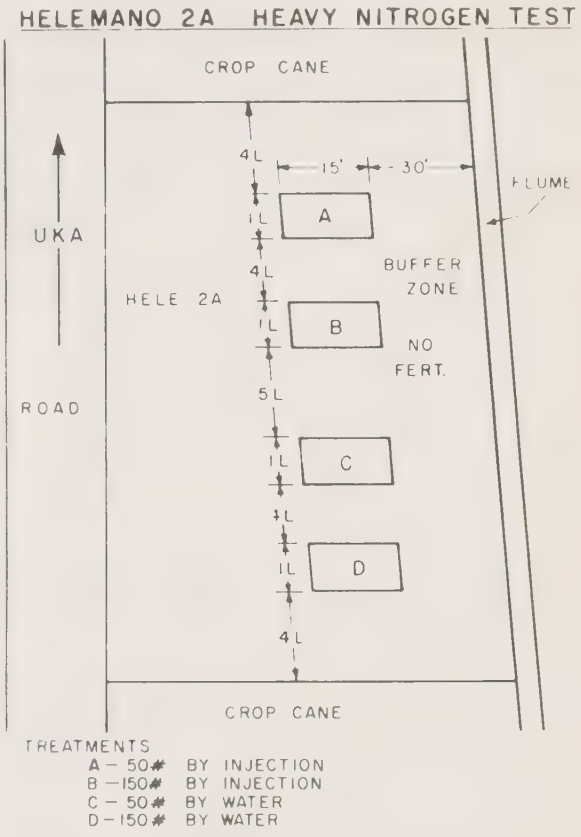


Figure 10. Experimental plots for N15 treatment.

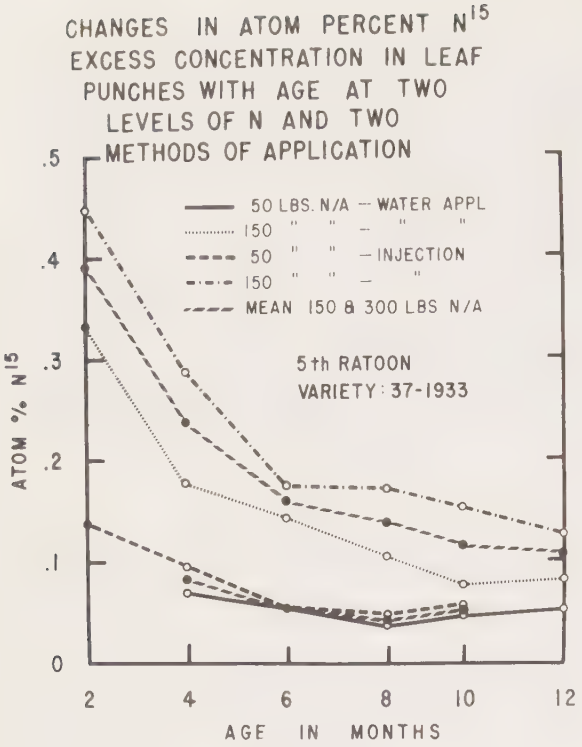


Figure 11.

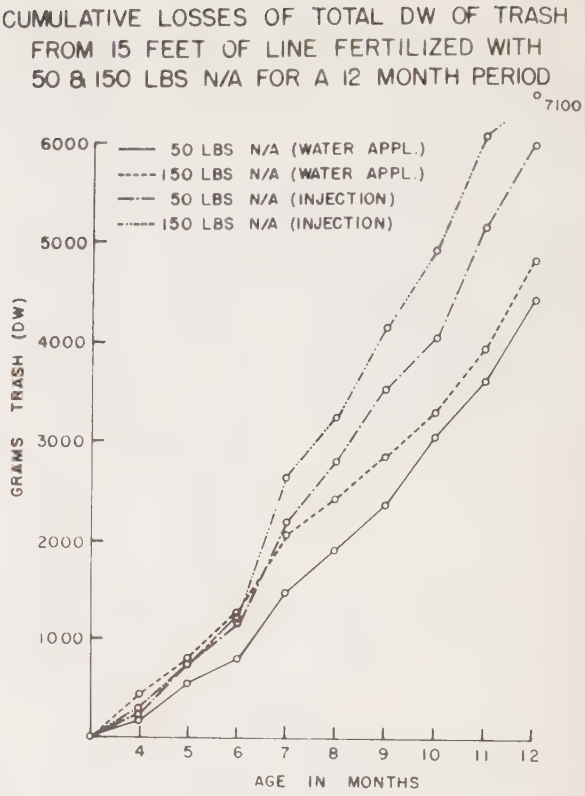


Figure 12.

Figure 12 shows the effect of the greater uptake of nitrogen on total leaf production. Dry leaves were quantitatively recovered monthly in each plot. The higher fertilizer application produced more leaves in each case. However, *the differences between injection and irrigation application were greater than the gain due to the extra 100 pounds of nitrogen.* Note that the two upper lines represent the result of injection.

The reasons for the greater availability of injected ammonia are not obvious. Irrigation water seeping directly over the entire stool might have been expected to result in a greater pickup of nitrogen. It may be that evaporation of NH_3 from the surface is appreciable. And it is also possible that NH_3 is so strongly adsorbed and that nitrification is so slow at the surface that percolation into a root zone is very slow.

However, it is clearly indicated that *a small portion of the total root system in contact with a rich band of nitrogenous fertilizer can readily supply the plant needs.*

Figure 13 shows the higher percentage of N15 in the larger bulk of trash, resulting in the striking differences in fertilizer nitrogen excreted by the plant.

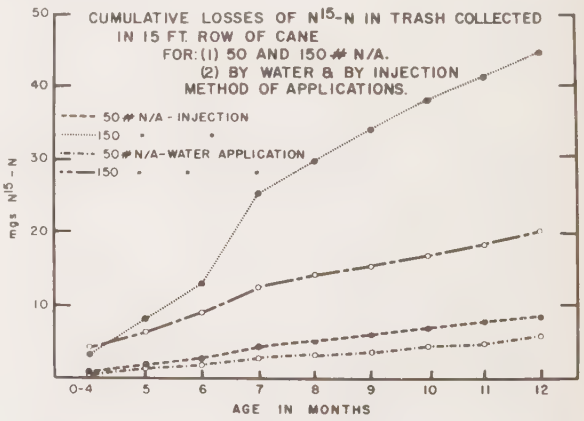


Figure 13.

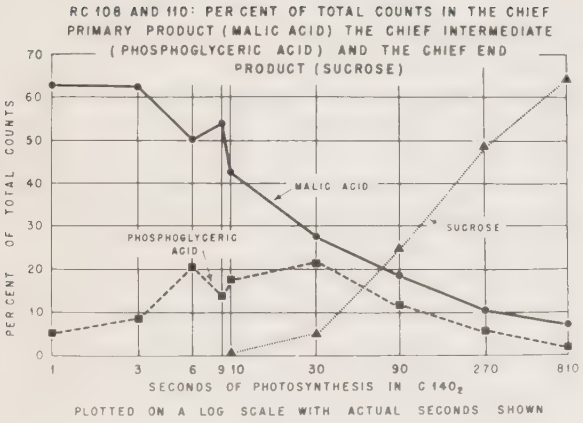


Figure 14.

NORMAL COURSE OF PHOTOSYNTHESIS IN SUGAR CANE

The use of radioactive carbon (C14) has greatly clarified the normal course of early photosynthesis in sugar cane. Tagged sucrose first appears about 15 seconds after the start of the experiment. The earlier intermediates appear in the sequence shown in Figures 14 and 15.

Cane leaves were dipped into radioactive CO_2 for periods ranging from 1 to 810 seconds and killed immediately. Sucrose made the most striking gain, rising from 199 counts at 10 seconds to more than a million counts at 810 seconds. Surprisingly, all but two components continued to gain with time. The only two constituents to reach saturation in this study were phosphoglyceric acid at 90 seconds and aspartic acid at 270 seconds. Phosphoglyceric acid is considered an intermediate in sucrose synthesis and aspartic acid in protein synthesis.

When plotted on the percentage basis malic acid was highest at the start, decreasing from 63 per cent at one second to 7 per cent at 810 seconds, and is therefore considered a primary product. Phosphoglyceric acid, an intermediate, reached its maximum percentage at 6 to 30 seconds. Other constituents which began low, increased to a maximum percentage, and then decreased, were glyceric acid, glucose–1–phosphate, fructose diphosphate, and fructose. A study of the time when each constituent reached its maximum per cent of counts indicates that they were formed in approximately the following order: malic acid (also aspartic acid), phosphoglyceric acid, glyceric acid, fructose diphosphate, glucose–1–phosphate, sucrose, fructose. Within an hour sucrose may constitute 80 to 90 per cent of the total photosynthate.

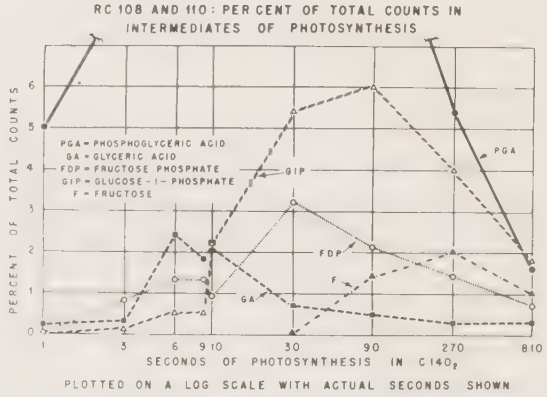


Figure 15.

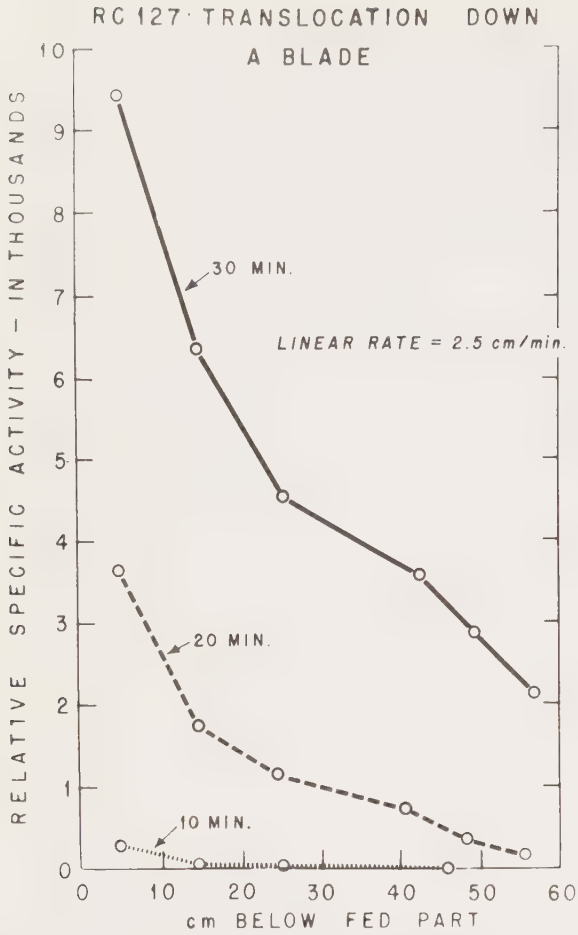


Figure 16. Newly made sugar moves rapidly down a blade toward the sheath.

SUGAR TRANSPORT A RAPID PROCESS

The normal transport of newly made sugars from the blade to growing parts and storage tissues is a relatively high-speed process whose mechanism is still poorly understood. Sucrose is the major material in the translocation streams.

Studies were made by clamping a feeding chamber on a portion of a leaf, injecting radioactive carbon dioxide and allowing a few minutes of photosynthesis in bright light. The chamber was removed and the tagged sugars were traced throughout the plant by periodic harvests.

Figure 16 shows the rate of movement down the blade itself during the 30 minutes following a feeding. In 20 minutes the new sugar has just reached the dewlap and in 30 minutes is well down the sheath. The linear rate is 2.5 cm. per minute.

After 90 minutes the new sugars have gone far down a mature stalk with 25 joints (Figure 17). Only 27 per cent of the total photosynthate is left at the site of feeding in blade 5. Very little of the sugars have moved upward, and the downward stream has largely by-passed the older leaves. It is interesting that the nodes are richer than the internodes, due probably to their greater content of vascular tissue. The linear rate, 1.87 cm. per minute, is somewhat less than found in the leaf experiment. However, these rates are many times the diffusion rates of sugars and no mechanism has been proposed which adequately accounts for the facts of translocation.

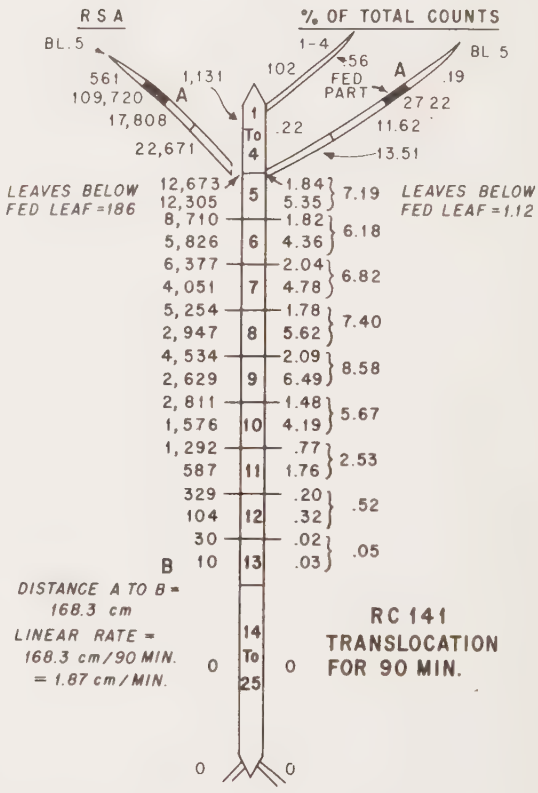


Figure 17. Translocation of C14 from fed blade 5 (shown twice in diagram). Separate counts for node and internode. Relative specific activity (RSA) at left; percent of total counts at right. Nodes richer than internodes in RSA but lower in percent because nodes weigh less. Sucrose had 85% of counts (and 92% of sugar counts) in internode 8.

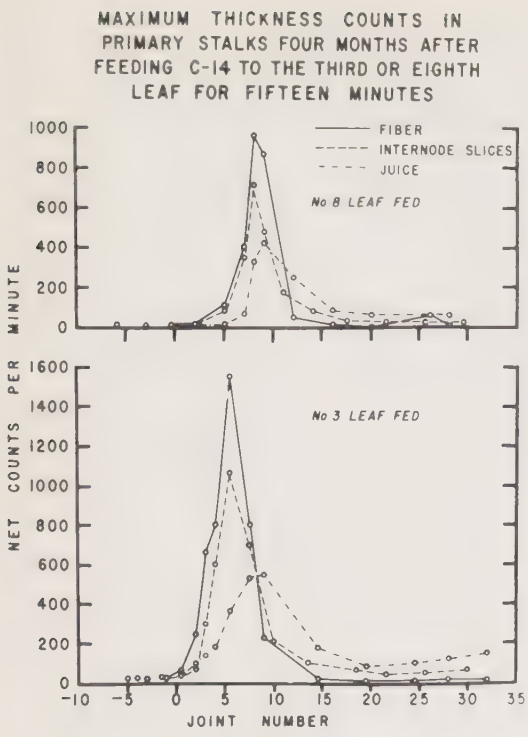


Figure 18.

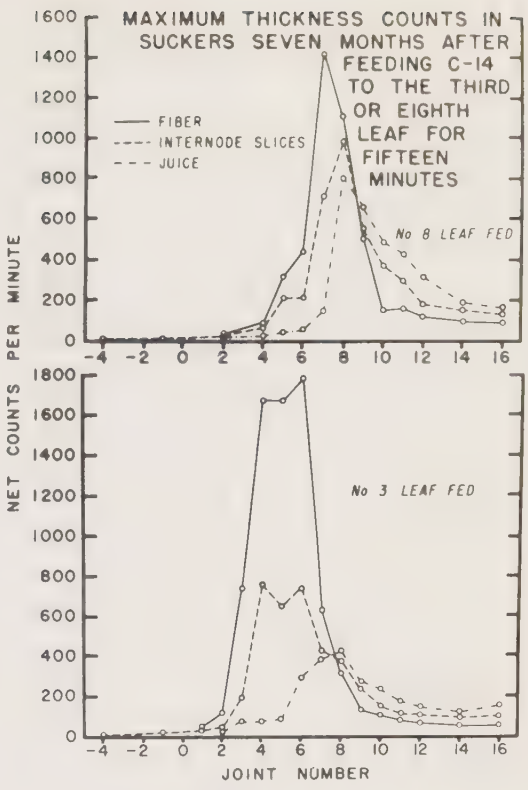


Figure 19.

WHERE IS SUGAR STORED?

Large primaries with 30 joints and neighboring suckers with 16 joints were chosen to find the final disposition of sugars made at a given moment. Following a 15-minute period of photosynthesis by either leaf No. 8 or leaf No. 3, the plants were left to grow for a number of months. After four months the primary stalks and selected joints were harvested. Juice containing the stored sucrose was expressed in an oil press and the residual fiber washed free of soluble matter. The suckers were left for seven months.

The very striking and highly reproducible results obtained are shown in Figures 18 and 19. The joint numbers apply to the day of feeding C14. The negative numbers represent joints made from the growing tip following the feeding.

The sugar which is made at a given moment is divided into two almost equal portions. One part goes to rapidly expanding joints and maturing joints to build fiber; the other remains as sucrose (chromatography has shown that the radioactivity of the expressed juice is entirely in the sucrose fraction). The position of the tagged fiber depends somewhat on the leaf fed. Sugar from leaf No. 8 enriches most of the fiber of joints 7 and 8; sugar from No. 3 builds more fiber in joints 4, 5, and 6. However, the location of stored sugar is independent of leaf fed and age of cane. It has maximum value in joint 8 in all canes. This is the region of rapidly maturing joints as represented by the 8–10 sample used in tissue diagnosis.

Very little fiber or insoluble material is formed in joints older than No. 15 of the mature cane. In the suckers which have only 16 joints these bottom parts are still laying-down cell wall. On the other hand, a fair amount of sucrose made months earlier is permanently located in joints all the way to the base.

The new joints (minus signs) show only the slightest trace of tagging, a rather surprising result in view of the rapid circulation of materials within the vascular system.

Table 9. Translocation of Radioactive Sugars into and Diffusion out of the Storage Cells of Sugar Cane

Internode No.	Sugar Content of Juice (%)		Percent Distribution of Radioactive Sugars In Juice Pressed from Cells		Diffused from Cells	
	Sucrose	Reducing Sugars	Sucrose	Reducing Sugars	Sucrose	Reducing Sugars
5 & 6	0.45	1.40	73	27	26	74
7 & 8	1.60	1.90	96	4	68	32
9 & 10	4.90	1.70	98	2	92	8

Radioactive carbon dioxide was fed to No. 7 leaf for 30 minutes and translocation allowed to continue for 24 hours. Juice samples were expressed from internodal tissues at a pressure of 1,000 lb/sq. in. This was analyzed for sucrose and reducing sugars and chromatographed to determine the distribution of radioactivity. Diffusion of radioactive sugars was determined by shaking discs of storage tissue in water for 4 hours after washing sugars from the outer spaces.

Table 10. Sucrose: Reducing Sugar Ratios of Total Sugars of Storage Tissues and of Radioactive Sugars Which Have Recently Diffused Into and Out of These Cells.

Internode No.	Total Sugars in Expressed Juice	Radioactive Sugars	
		In Expressed Juice	Diffused from Cells
	$\frac{S}{RS}$	$\frac{S}{RS}$	$\frac{S}{RS}$
5 & 6	0.32	2.70	0.35
7 & 8	0.84	24.0	2.13
9 & 10	2.88	49.0	11.5

Calculations from Data in Table 9.

Table 11. Accumulation of Radioactive Glucose and Sucrose into the Inner Space of Internodal Storage Tissue.

Internode No.	Tissue Sugars as Per Cent Dry Wt.		Tagged Sugar Uptake Mg/Gm Dry Wt/Day		Distribution of Cl4 Among Sugars Within the cell	
	Sucrose	Reducing Sugars	Fed Sucrose	Fed Glucose	Sucrose	Reducing Sugars
5	11.5	15.7	1.25		97	3
5	11.5	15.7		5.54	96	4
7	34.6	7.8	0.94		97	3
7	34.6	7.8		4.82	97	3
10	55.2	1.6	0.21		—	—
10	55.2	1.6		0.88	—	—
15	54.5	0.36	0.21		100	0
15	54.5	0.36		0.34	75	25

25 tissue discs were placed in 1.0 ml of solution containing 1 m of either C14-labeled sucrose or glucose and incubated for 4 hours at 25° C. The outer-space sugars were removed by washing and the inner-space sugars extracted in 70% ethanol for chromatography and assay of radioactivity. Sugar contents were determined on separate samples.

HOW IS SUGAR STORED?

A clearer insight into the mechanism of sugar accumulation by the cane plant has come by feeding radioactive sugars to storage tissue both *in vivo* and *in vitro*.

Dr. K. T. Glasziou of the Colonial Sugar Refining Company, Australia, collaborated with the Station in detailed studies of the effects of age of tissue and sugar content on: (1) relative rate of movement of sugars into storage cells; and (2) relative rate of leakage of sugars from storage cells.

Procedure was as follows: leaf No. 7 of a large, healthy cane plant was fed radioactive carbon dioxide for 30 minutes, and translocation was allowed to continue for 24 hours. Juice was expressed from selected internodal tissue at a pres-

sure of 1,000 pounds per square inch. This was chemically analyzed for sucrose and reducing sugars as well as chromatographed for the determination of radioactive sugars. Discs of storage tissue from the same internodes were washed free of extracellular sugars and incubated in water for four hours with gentle shaking. The radioactive sugars which leaked from the cells were determined after chromatography. Results in Tables 9, 10, and 11 clearly indicate the following conclusions:

1. The low purity in internodes 5 and 6 and the high purity in internodes 9 and 10 could be the result of: (a) reducing sugars being preferentially translocated upward and sucrose downward, or (b) some being hydrolyzed on entering younger tissues.

2. For 24 hours the newly formed sugars have retained their high sucrose/reducing-sugar ratios while admixed with the very low-purity sugars previously accumulated by the cells. This is evidence of very low enzyme activity. Reducing sugars leak from storage cells 5 to 10 times more rapidly than sucrose.

The reducing sugars which leak from the cells are primarily fructose, which is about 6 times the concentration of glucose.

3. The rate of accumulation of both sucrose and glucose falls rapidly with age of storage tissue.

4. Glucose enters the cells four to five times as fast as sucrose. This agrees fairly well with the greater leakage rate of reducing sugars.

5. Sucrose enters storage tissues with very slight changes while glucose is almost quantitatively changed to sucrose. The change is somewhat less complete in the very mature internode 15.

Hydrolysis of the sucrose thus made from glucose gives almost equal parts of radioactive glucose and fructose. This shows that as the glucose enters the membrane half is changed to fructose and the synthesis of sucrose is completed without having been freed for mixture with the large reducing-sugar pool in the vacuole.

CLIMATE AFFECTS GROWTH AND YIELD RESPONSES

Because the cost of obtaining data on soil temperature has been markedly reduced by the development of thermistors and suitable recording equipment, it has been possible to begin a project designed to augment the very meager data on soil temperature for the cane-growing areas of Hawaii. With the cooperation of the plantations, soil temperature data will be obtained at different locations in unirrigated cane fields.

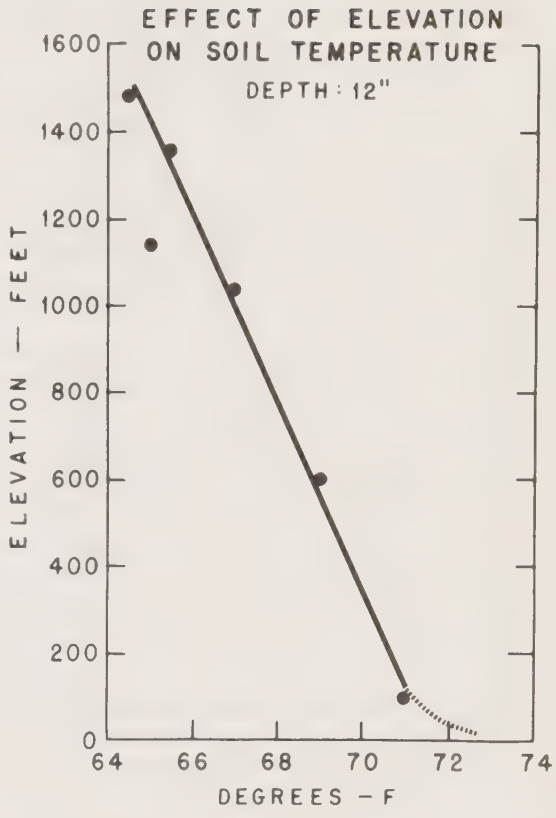


Figure 20.

Figure 20 shows the drop in soil temperature at the 12-inch depth with increase in elevation. These data were obtained during early March from fields of closed-in cane in a section of the Hamakua Coast. Studies at Makiki have established that optimum soil temperatures are above 72° F., and that temperatures of 62° F. are extremely limiting to top growth and to nutrient- and water-uptake. Hence, March temperatures along the Hamakua Coast are below optimum near sea level and are strongly limiting at higher elevations.

INFLUENCE OF TEMPERATURE ON NODE AND JOINT FORMATION

A recent climate-house experiment shows that, over the range of 56° to 74° F., the rate of node formation bears a straight-line relationship to air temperature (Figure 21). Root temperature also greatly influences node formation, probably because of diminished water and nutrients supplied by cooler roots.

Figure 22 shows the effect of root temperature on the metabolism of cane tops. Variety 37–1933 was permitted to develop a good stand after being planted in drums filled with soils from Lihue and Onomea. Then soil temperature in four of the drums was lowered to 62° F. while the other four drums remained at the mean air temperature of Makiki (75° to 80° F.). There was strong inhibition of top growth in the four drums subjected to several months of cool roots. Tables 12 and 13 show the results of studies of growth and composition of the plants in this experiment. The effects of root temperature on rate of joint formation is similar to those shown in Figure 21 for node formation. Low temperature affects leaf punch nitrogen and chlorophyll so strongly that the normal nitrogen decay curve disappears. In the presence of a plentiful nitrogen supply cooling of the soil reduced leaf nitrogen to a deficiency level.

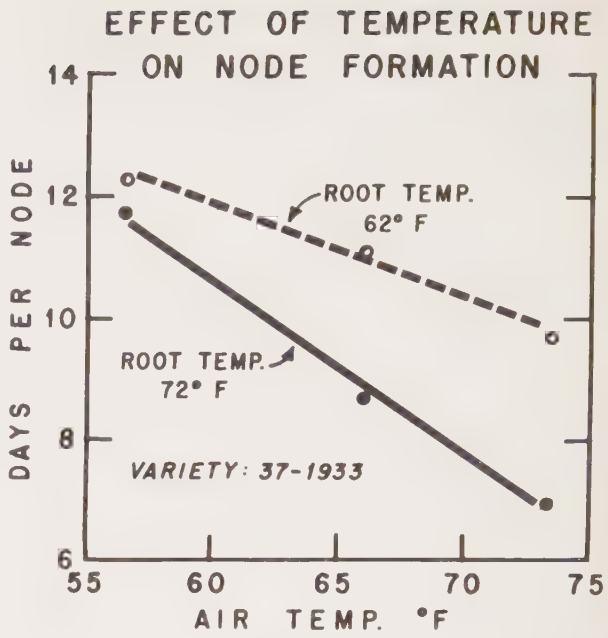


Figure 21.

Figure 22. Four drums at left show effect of several months of 60°F. root temperature.

Table 12. Effects of Root Temperatures on Rates of Leaf Unrolling and Joint Production*

Soil and Temperature	Joint Counts at 11/20/59	Joint Counts at 1/18/60	Net Joint Increase	No. of Days Per New Leaf	Joint Counts at 3/18/60	Net Joint Increase	No. of Days Per New Leaf
Lihue, 60° F.	10	14.9	4.9		17.2	2.3	
Onomea, 60° F.	10	15.8	5.8		18.3	2.6	
Average	10	15.35	5.35	11.4	17.8	2.45	17.5
Lihue, Makiki	12	19.3	7.3		22.9	3.6	
Onomea, Makiki	12	18.3	6.3		21.8	3.5	
Average	12	18.8	6.8	9.0	22.3	3.55	13.6

*Five plants studied in each drum. All soils fertilized at rate of 150 lbs. N, 150 lbs. K_2O, and 200 lbs. P_2O_5 per acre.

Table 13. Effects of Root Temperatures on Per Cent LPTN and Per Cent Chlorophyll.*

Soil and Temperature	11/20/59		1/11/60		3/11/60	
	% LPTN	% Chlorophyll	% LPTN	% Chlorophyll	% LPTN	% Chlorophyll
Lihue, 62° F.	1.54	.477	1.45	.419	1.55	.415
Onomea, 62° F.	1.30	.432	1.35	.493	1.67	.403
Lihue, Makiki	2.21	.706	1.96	.702	1.87	.642
Onomea, Makiki	2.01	.683	1.93	.631	1.91	.711

*Same plants as in Table 12.

PHOTOSYNTHESIS RATE DECREASED BY NUTRITIONAL DEFICIENCIES

A deficiency of any one of the major essential elements (N, P, K) reduces the rate of photosynthesis under otherwise optimum conditions.

Phosphorus deficiency depressed photosynthesis more than nitrogen or potassium deficiencies at the age of two months. Leaves of plants grown in water culture gave the following results when tested by the radiocarbon method. (TC = total counts per minute and measures amount of radiocarbon)

Series	TC/cm²	% decrease
Control	556	—
—P	208	63
—N	257	41
—K	449	19

Photosynthesis rates decrease with increasing severity of potassium deficiency.

A leaf portion showing no visible symptoms, and having a potassium percentage of 0.910, was decreased 10 per cent in photosynthesis compared with a control leaf (potassium percentage 1.70 to 1.89).

Leaf portions with edges dry and brown and having a potassium percentage less than 0.400 were decreased 84 to 98 per cent in photosynthesis compared with control leaves (potassium percentage 1.70 to 1.73). These tests were made by clamping a photosynthesis chamber across the middle of attached leaves.

For a more extensive experiment plants were raised in culture solutions lacking a single element. After the leaf analyses were well below the controls, mid-sections of No. 4 blades were transferred to the photosynthesis room and compared with their respective controls under standard conditions of temperature, light intensity, and CO_2 concentration. The results are summarized in Figure 23. The analytical data on the chart are very interesting. K did not depress N or chlorophyll below normal and had very little effect on photosynthesis at an analytical value of 0.355 per cent. Lack of P greatly depressed N and chlorophyll and cut photosynthesis rate markedly. Lack of N reduced chlor-

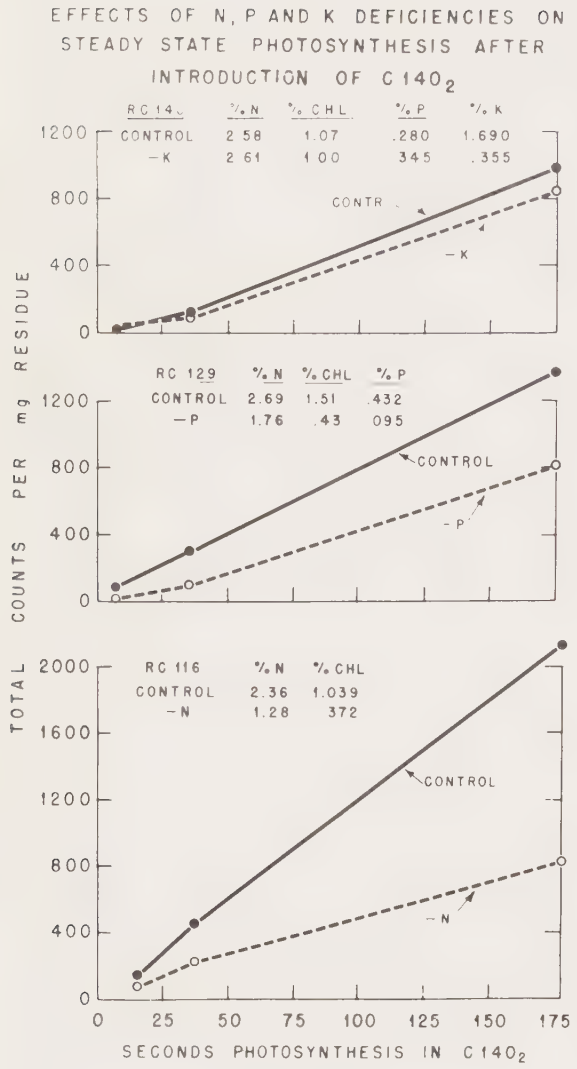


Figure 23.

ophyll to one-third the control, and photosynthesis rate fell to less than 50 per cent.

At the end of a 175-second photosynthesis test the blades were plunged into boiling alcohol and the extracts chromatographed. All early products of photosyntheses were reduced to much the same degree except that when P was lacking, the phosphorylated compounds (PGA, glucose–1–P and fructose-diphosphate) were exceedingly low. This occurred without a corresponding reduction in sucrose, the chief end-product.

TRANSLOCATION AFFECTED BY NUTRITIONAL DEFICIENCIES

This year 33 tests have been conducted to study the direction and rates of movement of C14 photosynthate in leaves and stem, as well as some of the environmental factors which increase or decrease this movement.

Downward movement of newly formed compounds proceeds at the rate of approximately 2.5 cm. per minute in a leaf growing on a well-fertilized plant in the field. This rate is less in plants suffering from a nutritional deficiency. Figure 24 shows the effects of N, P, and K. Apparently the low P content of this leaf did not materially reduce the rate of translocation. Nitrogen deficiency showed an intermediate effect while the lack of K reduced the linear rate to well below half that of the control.

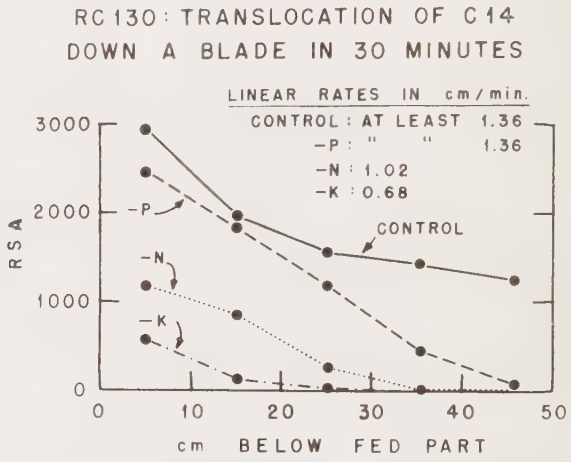


Figure 24. Effects of nutritional deficiencies on translocation.

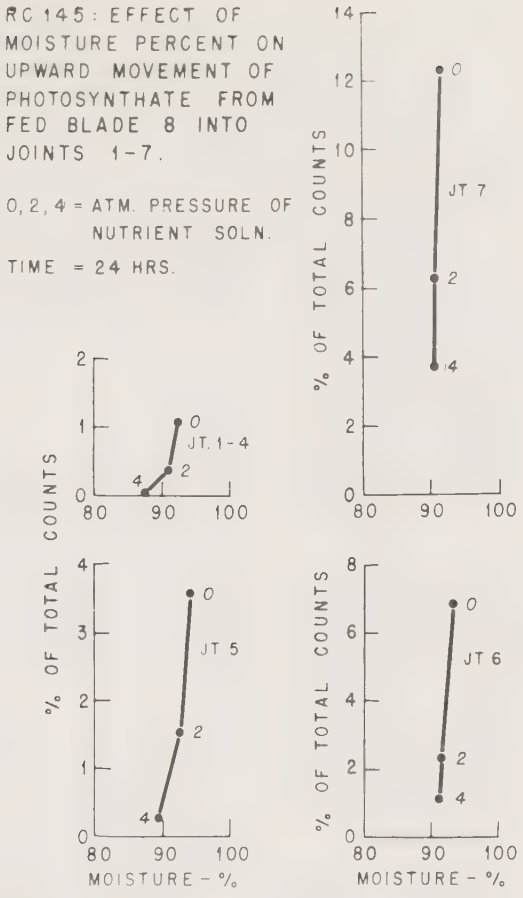


Figure 25. Moisture stress affects translocation.

TRANSLOCATION AFFECTED BY MOISTURE STRESS

Using the osmotic method of creating moisture stress in plants in culture solution, a study was made of the relation of reduced tissue moisture to the rate of translocation of newly made sugars into those tissues. Salt was added to the culture solution (0.4 atm.) to raise the osmotic pressure to 2.4 atmospheres and 4.4 atmospheres. The results are shown in Figure 25.

The effects of increasing moisture tension are progressively greater toward the growing tip in regard to both tissue moisture and translocation of newly made sugar. The moisture-drop below the control due to the application of an additional 4 atmospheres tension was found to be 0.9, 1.6, 3.2, and 5.0 per cent respectively in joints 7, 6, 5, and 1 to 4. At the same time the amounts of new sugars reaching these tissues, expressed as percentages of the control, were 30, 17, 7 and 4 per cent respectively. Growth of these young tissues is almost brought to a stop by 4.4 atmospheres tension and the demand for sugars is correspondingly reduced.

DISEASES

VARIETAL RESISTANCE TRIALS IN FIJI

The disease trials are being continued in Fiji in cooperation with the Colonial Sugar Refining Company, Ltd., and under the supervision of David Strong, to determine the resistance of Hawaiian varieties against Fiji disease and downy mildew.

During September 1960, an additional 30 Hawaiian varieties were sent to Fiji and planted in the Bekana quarantine area. These varieties will be included in disease trials following their release from quarantine.

Satisfactory results were obtained in the downy mildew studies; existing environmental conditions were favorable for the development of the disease. The results of the Fiji disease trials were moderately satisfactory; in some test areas a comparatively low degree of Fiji disease transmission occurred, therefore certain varieties will be retested. Ratings of varieties most promising in Hawaii are:

	DM	FD		DM	FD
39–5803	= —	+	50–2036	= —	= +
7028	+ +	+	6877	+	= —
44–2772	+ +	—	7209	= —	— —
48–514	=		51–760	+ +	
4046	+ +		4336	+ +	= —
4178	+	+ +	8194	+	+ +
49–5	+	+ +	52–123	=	— —
823	— —		6449	+ +	— —
3404	+ +	—	53–263	+ +	
4060	= —		1447	+ +	
50–723	= —	+ +	3989	—	

(+ values designate resistance; — values susceptibility)

MOLOKAI QUARANTINE

The Molokai quarantine has functioned efficiently in preventing the introduction of new cane diseases and insects into Hawaii with varieties imported for commercial and/or breeding purposes. During the year, 19 varieties completed their quarantine period and were released to Kailua Substation; 20 varieties ended their quarantine period in the small glasshouse and were released and planted under field quarantine; 19 varieties were received from Beltsville and Canal Point, and the 14 of these that germinated are growing satisfactorily under greenhouse quarantine.

LEAF SCALD RESISTANCE DEMONSTRATED

A leaf scald test installed at Kapoho, Puna Sugar Company, included 34 of the commercial and most promising varieties and the susceptible check variety, 28–4291. As each variety was ratooned, the freshly cut surfaces of the stubble were painted immediately with a pure culture of the leaf-scald organism and covered with cane trash to prevent the death of the organism from direct sunlight. All plots of the susceptible check variety were moderately to severely affected with leaf scald in the plant and ratoon crops, whereas, with the exception of 49–118 in the plant crop, symptoms of the disease have not developed on the other varieties. Apparently the varieties tested are moderately to highly resistant to leaf-scald disease.

RATOON STUNTING DISEASE AND VARIETIES

A varietal resistance test against ratoon stunting disease (RSD) harvested at 20.5 months at Waipio indicated different degrees of susceptibility and/or tolerance where the varieties were placed under severe stress by extending irrigation intervals. Yields from two replications of diseased and of healthy plots for each of seven varieties are shown in Table 14.

A seed area with healthy and RSD-inoculated cuttings of 16 varieties has been established at Waipio as a source of seed for additional resistance tests.

Table 14. Variety X Disease (N = 2)

Variety	TCA		PR		TPA		TPA
	H	D	H	D	H	D	H-D
45–2860..	88.6*	102.2	6.9	7.4	12.8	13.8	—
50–723...	92.9	97.3	7.6	8.2	12.3	11.9	0.4
39–3633..	123.9	106.0	6.8	6.9	18.2	15.3	2.9
49–134...	114.1	97.3	6.4	7.5	17.8	13.0	4.8
51–3049..	81.0	65.2	7.2	10.4	11.2	6.3	4.9
41–1045..	109.8	60.3	8.4	8.1	13.0	7.6	5.4
49–3404..	99.4	63.5*	7.5	11.2	13.3	5.6	7.7
HSD	21.1**				3.8**		

*A small amount of seed was accidently cut from a healthy plot of 45–2860 and from a diseased plot of 49 -3404

**Comparisons between healthy and diseased within a variety.

H = healthy D = diseased

In 1960, RSD was found in two seed areas. To control the spread of the disease, the supervisor in charge of seed cutting should spot-check basal cuttings for symptoms of the disease during seed cutting operations. If RSD is found in a variety that is being spread, it is advisable to establish new seed areas with heat-treated cuttings (LHWT, 50° C. for 2 hours, or HAT, 8 hours at 54° C.). The LHWT has given 95 to 100 per cent control of RSD, but it is important to continue inspecting the seed areas and to establish new LHWT areas if RSD symptoms are present.

RED ROT TESTING CONTINUED

All commercial and the most promising varieties were tested against red rot at the Lihue Variety Station. Seven commercial varieties were tested at Hawaiian Commercial & Sugar Company with the red-rot organism isolated from Field 100 (isolate A) in 1958 and from Field 200 (isolate B) in 1960.

The variability of resistance to disease within varieties may fluctuate within small ranges due to such factors as temperature, soil moisture, and light. The possibility of new races becoming established from the red-rot organism makes it necessary to test the same varieties periodically under different environmental conditions. Red rot was causing moderate to severe damage to variety 38–2915 in 1960.

FUNGICIDES TESTED AGAINST PYTHIUM ROOT ROT AND PINEAPPLE DISEASE

New chemicals have been screened for their fungicidal properties against *Pythium graminicolum*, the root-rot organism, and *Ceratocystis paradoxa*, the pineapple-disease organism. Of 90 chemicals tested, 23 effectively inhibited *Pythium* in the laboratory, whereas only seven were sufficiently promising against *C. paradoxa* to warrant further testing. Some control of pineapple disease was indicated in tests with Osamine and with two mercurial fungicides, phenyl mercury oleate and phenyl mercury napthanate.

Chemicals found promising in the laboratory will be further studied as to their range of toxicity to both *Pythium* and sugar cane and the most promising ones tested for the control of *Pythium* root rot of sugar cane in seedling flats and in pots before being tested in the field. In the case of pineapple disease, the chemicals will be tested under field conditions where the cost is not too high to compete with phenylmercuric acetate.

Several fungicides found promising in laboratory tests last year were screened in the greenhouse using seedling flats. Of these, Hercules 3944 and 4223 controlled *Pythium* satisfactorily for one week at solution concentrations of 200 ppm and 400 ppm. Weekly applications to the seedling flats of a 200-ppm solution of either fungicide appears necessary to effectively control *Pythium* infection of the seedlings. Olin Matheison's fungicide #1564 also appears promising and results indicate that seedling flats need to be drenched at weekly intervals with at least a 500-ppm solution for reasonable control of *Pythium* root rot.

Dexon (p-Dimethylaminobenzenediazo sodium sulfonate, formerly designated as Bayer 22555) was tested against Captan for the control of *Pythium* root rot of sugar cane seedlings in flats placed in the open at the Station. The fungicides were applied weekly during wet weather and once every two weeks when the weather was drier. *Pythium* root rot did not develop in the seedling flats treated with Dexon, whereas there was some *Pythium* infection in the Captan-treated flats and in the untreated checks.

REACTION OF LEADING VARIETIES TO PYTHIUM ROOT ROT DISEASE

A replicated pot test was designed and installed to determine the reaction of six of the leading commercial varieties, 37–1933, 39–7028, 44–3098, 49–5, 49–3533, and 50–7209, to *Pythium* root rot. The test was carried out in both an unfumigated and a methyl-bromide fumigated Makiki compost soil.

At the end of 3½ months, dry weights in grams of the tops and thoroughly washed roots were taken, counts of secondary shoots made, and the data statistically analyzed. Table 15 shows the significant reduction in both top and root growth for all varieties due to *Pythium* in both the fumigated and unfumigated soils, with the probable exception that *Pythium* did not appear to affect root growth of 49–5 in the unfumigated soil. The effect of *Pythium* was greater in the fumigated than in the unfumigated soil in all cases.

Fumigation alone (in the absence of *Pythium*) produced a significant increase in top growth but no significant increase in root growth.

Pythium caused a significant reduction in secondary shoot development of all varieties in both the unfumigated and fumigated soils, with 49–5 being a probable exception in that secondary shoot development was greater in the unfumigated-inoculated than in the unfumigated check soils.

Fumigation alone caused no significant increase in secondary shoot development when compared to the unfumigated controls.

Table 15. Summary of Average Measures

Fumigation x *Pyth. gram* (P) (n = 18)

Fumigation	Tops		Roots		Shoot Counts	
	X	P	X	P	X	P
UF	134.7	113.1	32.8	25.6	7.4	5.4
F	164.4	20.1	33.5	4.5	8.1	0.4
HSD	11.3		5.7		1.2	

Figure 26 illustrates the differences in top growth of 37–1933 at the end of two months and the differences in root growth at the end of 3½ months.

This test will be repeated before final conclusions are drawn.

Figure 26. Effects of **Pythium** on 37-1933.

A. top growth (2 months) B. root growth (3½ months)

F — X = fumigated control; F + P = fumigated + **Pythium**;
UF — X = unfumigated control; UF + P = unfumigated + **Pythium**

POTENTIALLY TOXIC NITRITES IN SUGAR CANE SOILS

Nitrites are known to be toxic to many plants and it is important to know if the amounts formed in some sugar cane soils are high enough to cause an appreciable reduction in yield.

Nitrites may temporarily accumulate in soils under aerobic conditions, the pH of the soil being a determining factor. Under alkaline conditions free ammonia may be formed in amounts toxic to the group of bacteria converting nitrite to nitrate; as the concentration of ammonia decreases, the bacterial oxidation of nitrite to nitrate proceeds more rapidly. The group of bacteria converting ammonia to nitrite is less sensitive to ammonia, resulting in the temporary accumulation of nitrite. The amounts of nitrite which accumulate will depend upon the amounts of ammonium added to the soil.

Studies were conducted to determine whether nitrites do accumulate in sugar cane soils to which $(NH_4)_2SO_4$ or NH_4OH is added, and to study the effects of varying amounts of nitrite on the growth of 37–1933 and 50–7209.

In an acid soil (pH 4.3) little or no nitrites accumulated when the soil was amended with $(NH_4)_2SO_4$ at the rate of 500 ppm N and with NH_4OH at rates as high as 1,500 ppm N. In a neutral soil (pH 6.8) in four weeks over 300 ppm nitrite-N accumulated from 1,500 ppm N as NH_4OH, and at 12 weeks 30 ppm nitrite-N remained. In one week an alkaline soil (pH 8.0) accumulated 300 ppm nitrite-N from 500 ppm N as $(NH_4)_2SO_4$ and NH_4OH; 1,500 ppm N as NH_4OH caused 300 ppm nitrite to accumulate in four weeks, oxidation to nitrate being complete in 12 weeks.

Nitrites appear more toxic to sugar cane in acid soils than in neutral or alkaline soils. Considerable amounts of nitrite (160 ppm NO_2–N or more) were found necessary to cause visible injury to both 37–1933 and 50–7209.

SOIL FUMIGATION TO CONTROL FUNGI AND NEMATODES

Pot studies have shown that *Pythium* root rot can be controlled with specific fungicides. Of the many chemicals tested, Dexon, followed by Captan, are the two outstanding ones. In preliminary field studies a satisfactory control of root rot has been obtained in a few areas with Dexon; however, the rates and frequency of application of Dexon must be determined before its economic value is established. The rates used in preliminary studies make it too costly to be used on a field scale.

Some of the soil fumigants are also effective in controlling *Pythium* and other soil organisms. Methyl bromide, applied at the rate of 2 pounds per 100 square feet, is highly effective for reducing all forms of soil organisms but here again the cost of application precludes its field usage.

Trapex (EP–161) and EP–162, two new experimental soil fumigants manufactured by the Morton Chemical Company, appear promising for the control of *Pythium* in soil. *Pythium* root rot of 37–1933 was effectively controlled in pot studies and an observational field test has been installed with both fumigants at Hilo Sugar. Both fumigants are claimed to be effective fungicides as well as nematocides. The fungicidal properties of Trapex are illustrated in Figure 27.

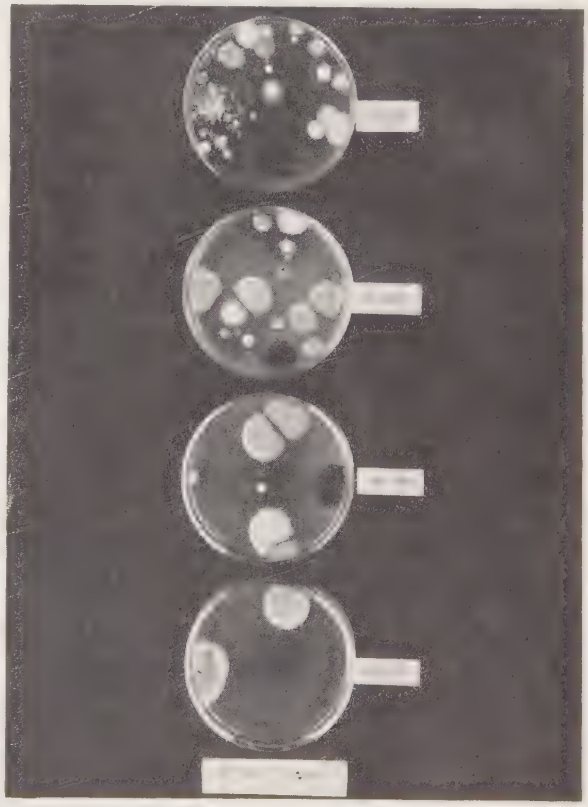


Figure 27. Effects of varying rates of Trapex on types and numbers of fungi in soil.

In pot and field experiments, nematode control has been effected in some areas by preplant-treating the soil with DD, EDB, methyl bromide, Trizone, and BBC (1–2 Dibromo–3–chloropropane). Of these, DD, EDB, and BBC are the only ones which may be used economically on a field-cost basis. Since methyl bromide and other fumigants are highly effective for controlling both nematodes and fungi in the soil, it is hoped that cost of fumigation can be reduced.

IDENTIFICATION AND DETERMINATION OF PATHOGENICITY OF NEMATODES ON SUGAR CANE

Cooperative work with the University of Hawaii on nematode research brought forth the following information.

1. Nematode Survey at Waialua

A study was carried out in relation to nematode population variations in fields with respect to soil type, elevation, and variety. Eight genera of plant-parasitic nematodes were found in these studies: the spiral, root-knot, lesion, stubby-root, dagger, burrowing, pin, and ring nematodes. The survey included 70 fields sampled from September 1959 to February 1960.

The lighter soils (Lahaina, Wahiawa and Kahana types) supported higher populations than the heavier types (Waialua and Kawaihapai). An increase in population occurred with an increase in elevation, possibly associated with the lighter soils at the higher elevations. A wide range in population was noted with varieties, but these differences may be explained on soil types since nematode populations in the case of 37–1933 and 50–7209 did not vary greatly when grown in the same soil types.

2. Nematode Garden

Pure cultures of nematodes suspected of being pathogenic to sugar cane are being established in pots of sterilized soil where the variety 37–1933 has been planted. Such a garden will supply sources of nematodes for future experimental work.

3. Varietal Susceptibility to the Root-Knot Nematode

Varieties 37–1933, 39–7028, 44–3098, 49–5, 49–3533, and 50–7209 were grown in methyl-bromide fumigated Makiki soil and unfumigated soil both with and without the root-knot nematode. The root-knot inoculum was prepared from macerated galled tomato roots. Six replications of each treatment were used and the test was harvested at the age of four months. No significant differences were found in dry weights of top growth for the varieties, treatments, interaction between the varieties and treatments or replications.

This test, conducted during optimum growing conditions, did not confirm the results in a similar test conducted by Dr. W. J. Apt under less favorable growing conditions where reduced top growth was significant with 37–1933 in root-knot inoculated soil. There was an increase in tillering, as a result of inoculation with root-knot nematodes, that was significant at the 5 per cent level.

GROWTH OF 32-8560 GREATLY STIMULATED BY SOIL FUMIGANTS

It may be assumed that the marked top and root development in the fumigated plots in Field 101P at Hamakua Mill Company is due, chiefly, to the reduction of nematode root damage by soil fumigation. This test was installed in October 1959 and the fumigants were injected into the soil at the following rates: check, no special treatment; DD, 40 gallons per acre; Brozone, 300 and 200 pounds per acre; and Trizone, 200 and 140 pounds per acre. The Brozone and Trizone plots were covered with a 2-mil polyethylene cover immediately following the injection of the fumigants.

Figure 28 shows the effects of fumigation on root development in studies conducted by Y. Yamasaki and H. Asato in June 1960. With the deeper and more extensive root systems in the treated plots, more moisture and mineral elements were available for growth and the plants were able to withstand the low soil-moisture conditions which have prevailed periodically since the test was installed.

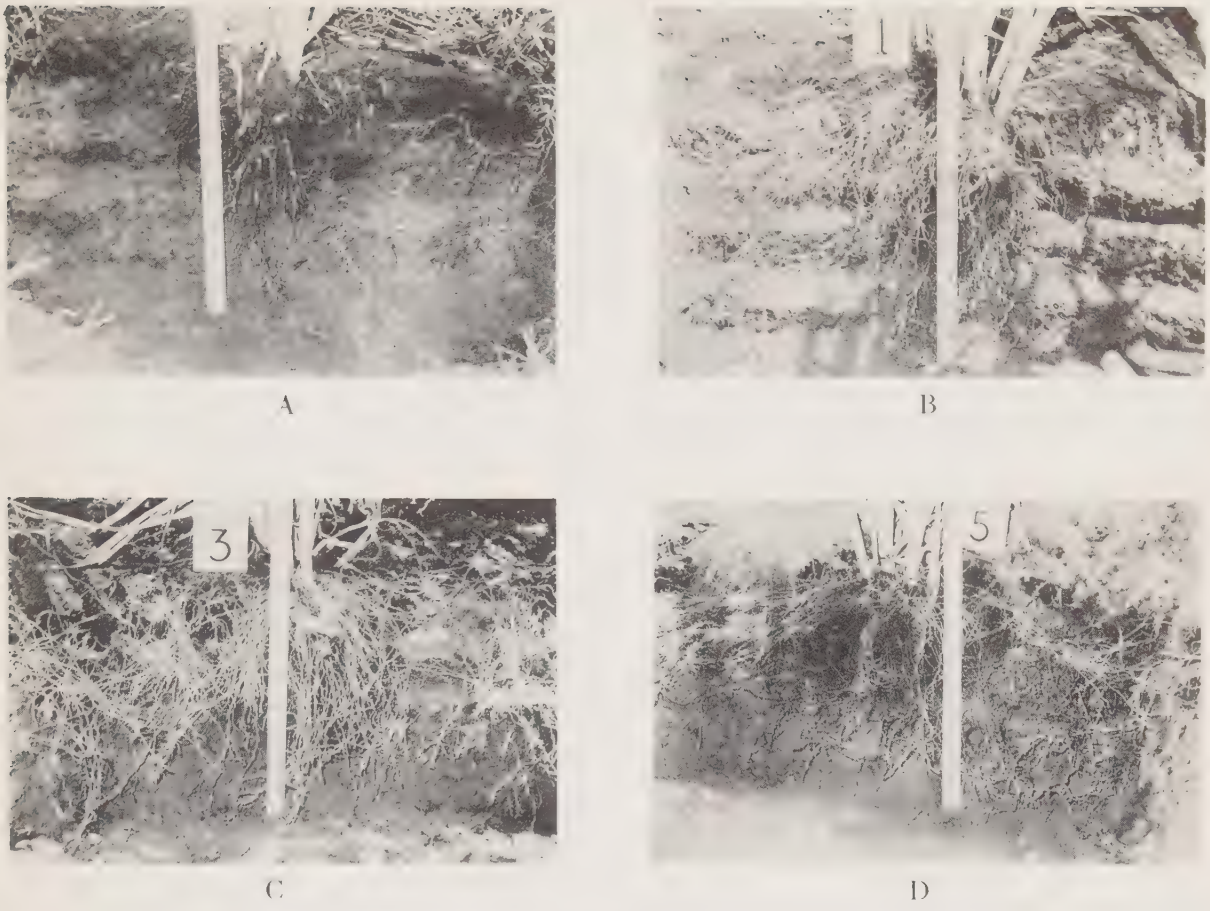


Figure 28. Root development of 32-8560 greatly stimulated in experiment at Hamakua.

A. check B. DD, 40 gals/acre

C. Brozone, 300 lbs/acre D. Trizone, 200 lbs/acre

EXPERIMENTAL STATISTICS

COMPUTING CENTER SPEEDS UP RESEARCH DATA ANALYSIS

The computing center established in cooperation with the Pineapple Research Institute in September 1959 has operated at or near capacity of the equipment. During the first four months a library of programs was established for machine-processing of routine computing jobs. The first year's operation has shown that a satisfactory job in one area led to a request for computer time from another area, and that the load on routine work developed so rapidly that less than anticipated time was available for other problems. A large block of time was used in a sizeable number of studies involving the harvesting of experimental plots. The computer also provided service on irrigation studies directed at the estimations of infiltration rates and other factors bearing on irrigation practices. A marked increase in the number of regression studies also placed heavy demands on computer time.

The center has been of assistance in research planning. An expanded program on irrigation is now under way using the computer for data reduction. Other applications of the computer are being developed and will be used as soon as practicable.

NEW COMPUTER ORDERED

Scheduled for arrival early in December is a new solid state computer to replace the present installation. The new data-processing system, the IBM 1620, is a transistorized high-speed machine with a core memory of 20,000 digits and with three programming systems: Symbolic, Fortran, and Gotran. The new computer will speed present programs and will alleviate the existing lack of computer time.

CORE SAMPLER SIMPLIFIES TRASH ESTIMATION

At the request of Puna and in cooperation with the Field Engineering Department, a sampling study on methods of estimating per cent tare was carried out. The standard method is use of the grab to obtain approximately 1,000 pounds of cane; this is weighed, stripped, sound cane weighed, juice sample obtained from the latter material, etc. A practical alternative is the use of the core sampler designed by Field Engineering to remove about a 50-pound sample from the truck load.

The tare estimates showed virtually no difference. A total of 45 truckloads of cane were sampled, each load being sampled by both methods. The mean difference in tare was less than one per cent.

The sample sizes differed by a factor of 20, suggesting that there could be a big difference in precision. Each load was sampled by obtaining duplicate samples for each method. This provided estimates of the 'within load' variation and, while the core samples were more variable, the difference in the level of variability was only 3.4 per cent. Since the level of sampling variation for *both* methods fell in the range 20 to 25 per cent, it is obvious that an increased sampling rate is desirable. Only the core sampler offers possibilities for increasing the sampling rate, since it can go to the maximum of sampling every truck with no increase in labor cost.

SAMPLING PLOTS FOR POL RATIO

In a study of the grab as a suitable device for taking cane samples a routine experiment on Oahu was sampled, using duplicate grab samples per plot and drawing duplicate 2-pound samples of chopped material from each grab sample. The variation between 2-pound samples within plots generally ranges from about 2 to 4 per cent. The variation between grab samples within the plot was 4.3 per cent while that for variations between samples within grabs was 2.6 per cent. A sampling variation of less than 5 per cent is reassuring and should permit the use of this method with a considerable degree of confidence, particularly considering the probable cost of presently available alternatives.

FACTORY

CANE DIFFUSION PILOT PLANT INVESTIGATION COMPLETED

Investigational work on the experimental diffusion plant (Figure 29) installed at Kekaha Sugar Company was completed in July. Observations during the year extended those of 1959 to the point where information necessary for commercial application was obtained.

The investigation demonstrated that commercial-type machinery is capable of reducing cane to a fine state from which the juice can be washed with a reasonable quantity of water and from which the fiber can be pressed into bagasse suitable for fuel.

A summary of analytical data for 1960 operations is given in Table 16. The figures are grouped according to bagasse pol. Under this grouping, percentage of extraction ranged from 98.8 down to 95.6 with an over-all average of 96.9. Dilution on absolute juice varied in the same order from 52 to 38 per cent. These figures, of course, indicate both good and bad conditions. Examination of data obtained under optimum conditions shows that extraction in the area of 98 per cent can be obtained at dilutions around 45.

The principal factor determining extraction is the degree of preparation of the cane. With unsatisfactory preparation, even high dilution will not give high extraction. Test procedures show that cell rupture of 94 per cent is desirable. Thus the process becomes essentially one of washing or leaching rather than of diffusion as a large portion of the juice remaining in unopen cells is removed only in the final dewatering step. Figure 30 shows well-prepared bagasse from the press.

Clarification studies showed that juice from the pilot plant presented no problems and the results were comparable to those obtained with mill juices.

Sugars boiled from the diffusion juices proved to be comparable in quality to those boiled from

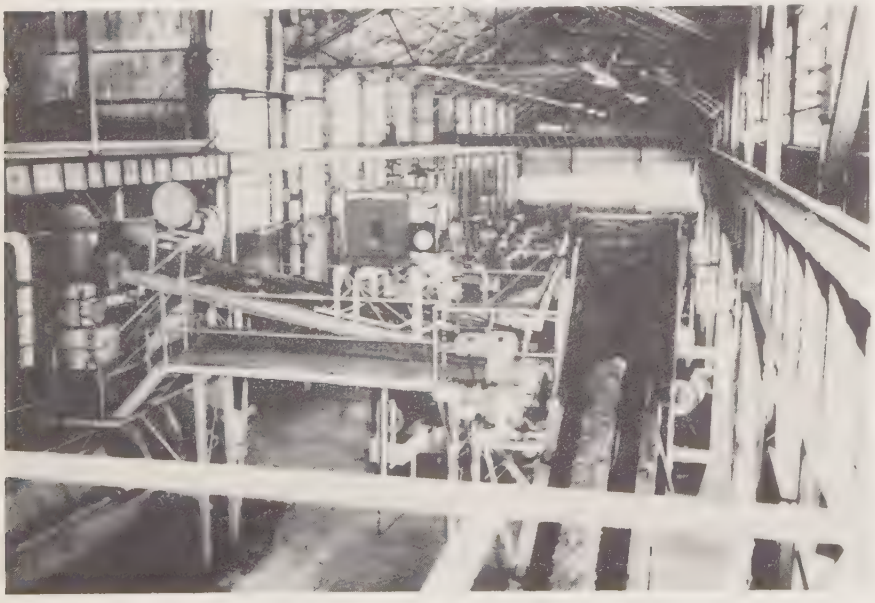


Figure 29. Diffusion installation at Kekaha.

Table 16. Summary of Diffusion Analytical Data—1960
(Grouped by Bagasse Pol)

	Below 0.80	0.80-0.99	1.00-1.19	1.20-1.39	1.40-1.59	1.60-1.79	1.80-1.99	2.00-2.19	Av.
No. of Samples	(5)	(15)	(26)	(15)	(22)	(17)	(13)	(8)	
Cane									
Pol, %	11.6	11.9	12.2	12.0	12.6	12.3	12.6	12.9	12.3
Fiber, %	12.6	13.0	13.5	13.2	13.3	13.3	12.8	13.0	13.2
Absolute Juice									
Ref. Sol., %	16.0	16.5	17.0	16.9	17.3	17.0	17.0	17.3	17.0
Pol, %	13.3	13.7	13.9	13.8	14.5	14.2	14.4	14.8	14.2
Purity	83.1	83.0	81.8	81.7	83.8	83.5	84.7	85.5	83.5
Wet Bagasse									
Pol, %	0.88	0.97	1.39	1.27	1.45	1.42	1.60	1.48	1.3
Moisture, %	85.6	85.2	84.8	84.8	84.9	83.5	84.4	83.7	84.7
Fiber, %	12.8	13.1	12.9	13.2	12.8	14.2	13.1	14.1	13.2
Press Bagasse									
Pol, %	0.58	0.91	1.11	1.28	1.49	1.70	1.91	2.08	1.4
Moisture, %	45.5	49.8	48.9	49.1	48.6	48.9	50.8	49.1	49.2
Fiber, %	53.5	48.6	49.3	48.8	49.0	48.4	46.2	47.8	48.6
Calc. Pol, %	0.44	0.55	0.58	0.68	0.70	0.81	0.94	1.02	0.7
Pol, Actual/Calc.	1.32	1.65	1.91	1.88	2.13	1.20	2.03	2.04	2.0
Diffusion Juice									
Ref. Sol., %	10.54	10.82	11.21	11.38	11.36	12.01	12.30	12.31	11.5
Pol, %	8.97	9.11	9.38	9.45	9.55	10.00	10.44	10.48	9.7
Purity	85.1	84.2	83.7	83.0	84.1	83.3	84.9	85.6	84.0
Press Juice									
Ref. Sol., %	1.67	1.86	1.88	2.12	2.21	2.49	2.72	2.94	2.2
Pol, %	0.94	1.07	1.14	1.32	1.37	1.57	1.74	1.95	1.4
Purity	56.3	57.5	60.6	62.3	62.0	63.1	64.0	66.3	62.1
Dilution % Absolute Juice	52	52	52	49	52	42	38	41	47
Extraction	98.8	98.0	97.5	97.1	96.8	96.2	95.8	95.6	96.9

mill juices. Refinability tests on the sugars made by the C&H technical staff at Crockett indicated that the sugars were somewhat better than the sugars from mill juices, in particular because they were of lower ash content.

The economics of this type of cane processing appears favorable compared with milling in the following points:

1. Higher extraction is more readily attained.
2. Capital costs have lower estimates.
3. Power requirements are less.
4. Maintenance costs should be substantially lower.

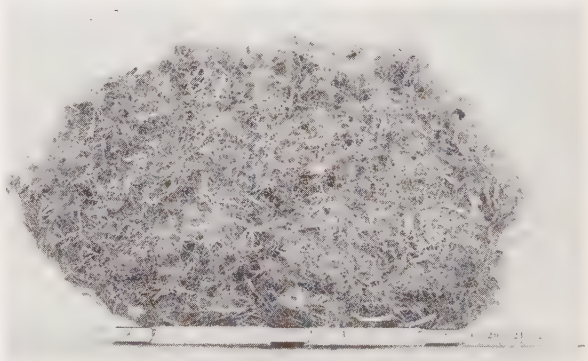


Figure 30. Bagasse from diffusion plant at Kekaha (dried and pressed).

SUGAR CRYSTAL CONTAINS MANY INGREDIENTS

Major attention in the sugar quality program has been given to the quantitative determination of the non-sucrose materials present in the crystal.

Water: Water is present both on the surface and within the crystal. Figure 31 shows schematically the high-vacuum apparatus constructed so that a quantitative determination of both could be made by measuring vapor pressure. Measurements were completed on two sizes of refined sugar, small-crystal granulated and large-crystal Confectioner's A. Granulated contained 0.047 per cent water internally, 0.01 per cent externally; Con. A contained 0.157 per cent internally and 0.005 per cent externally. These results show that the internal water in the crystal is much greater than on the surface. The very large amount found within the large crystals is indicative of much greater inclusion of mother liquor.

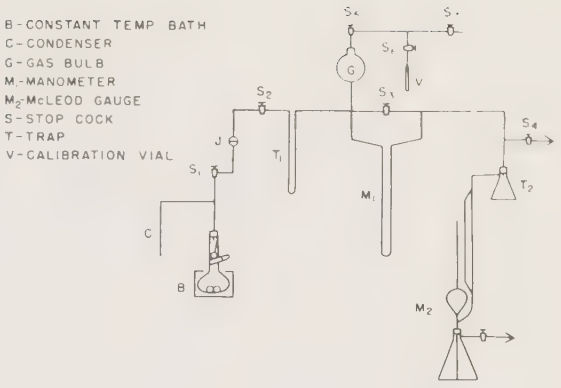


Figure 31. High-vacuum system for measuring internal moisture in the sugar crystal.

Inorganic Compounds: Figure 32 shows the results of an ion-exchange procedure developed to separate the inorganic cations present in the crystal. Results on a commercial sugar of high crystal color and one of low crystal color, as shown in Table 17, show a relationship which again indicates inclusion as a major factor in crystal quality.

Starch: Results of a method for determination of starch in the crystal (Figure 33) are shown in Table 18.

Statistical analysis of the results gives a correlation coefficient of 0.70 between starch and filtration rate. This indicates that half of the variation can be attributable to starch. If, however, only the results from the island of Hawaii are considered, the correlation coefficient is only 0.27. This means that starch is a very minor factor in those results accounting for only 7.4 per cent of the variability in filtration rate.

Polysaccharides: Polysaccharides other than starch are also present in the sugar crystal. Results of chromatographic analysis (Figure 34) are shown in Table 19.

The relationship between these substances and refinability remains to be established.

Color Compounds: A technique has been developed using dimethylformamide as a solvent for fractionating the substances in the crystal. The results show the relationship between color and four classes of substances: (1) phenolic and polyphenolic substances, (2) ketoses and degradation products of reducing sugars, (3) amino compounds, and (4) some inorganic constituents. The color and intensity vary with the physical and chemical states of the compounds and the extent of their interaction.

Table 17. Analysis of Sugar Crystal

Sample	Color a*420x10	85% Methanol Insoluble	SiO_2	Na	K	Mg	Ca	Fe	Al
			ppm						
I	4.0	0.107%	38	7	165	11	7	9	4
II	13.0	0.199%	180	156	296	53	49	43	84

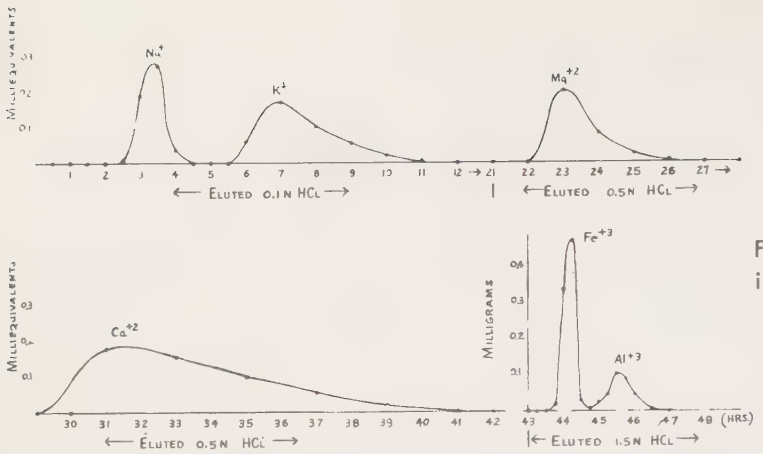


Figure 32. Separation of cations in sugar crystal by ion exchange.

Table 18. Analysis of Sugar Crystal

Sample	Filt. Rate	°St.	Color a*420x10	Starch ppm
Lihue	n.a.*	n.a.*	10.6	78
Papaaloa	n.a.	n.a.	7.1	133
Waialua	n.a.	n.a.	4.7	29
Wailuku	n.a.	n.a.	13.4	50
Pepeekeo	n.a.	n.a.	4.1	170
Kekaha	111	3.9	4.6	32
McBryde	101	5.6	7.1	31
Kilauea	79	5.9	7.1	74
Ewa	96	2.8	3.4	18
Kahuku	117	3.5	4.1	30
Wailuku	103	5.0	6.0	20
Pioneer	101	3.3	4.0	30
Hutchinson	64	6.1	6.6	69
Hawn. Agr.	72	3.8	4.5	113
Puna	86	3.7	4.6	141
Onomea	75	3.0	4.0	90
Pepeekeo	89	4.1	5.0	65
Laupahoehoe	72	5.1	6.4	83
Hamakua	67	8.4	11.0	90
Honokaa	85	4.3	5.3	98

*Not available.

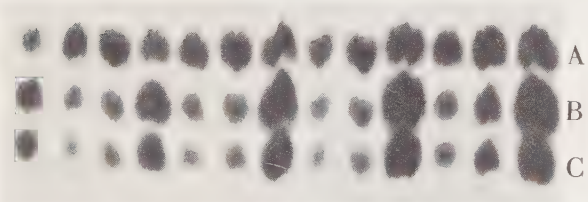


Figure 34. Chromatographic separation of polysaccharide hydrolysis products from commercial sugar crystal.
A — glucose B — arabinose C — xylose

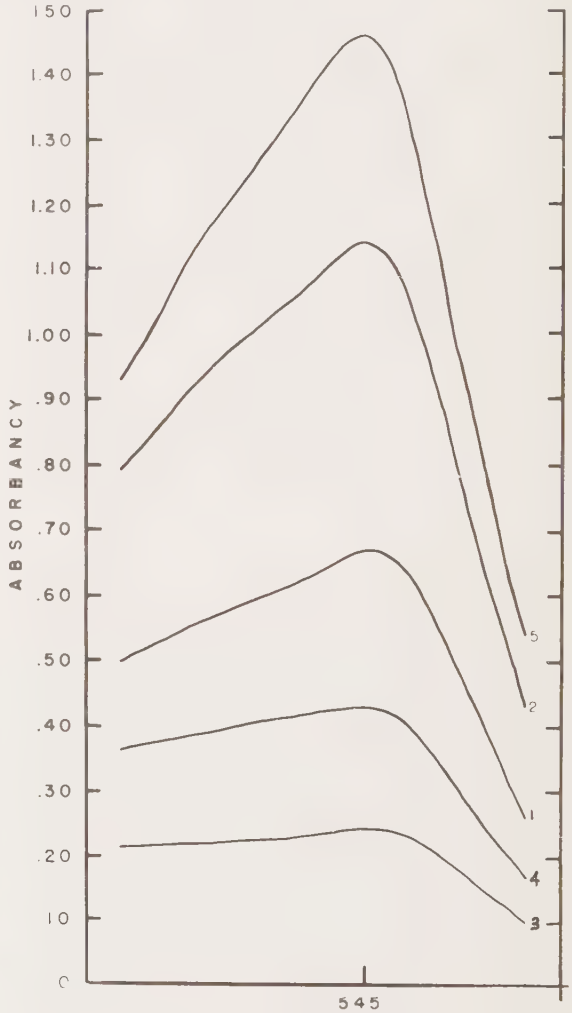


Figure 33. Typical absorbency curves used in determining starch in commercial sugar crystal.
1. Lihue
2. Papaaloa
3. Waialua
4. Wailuku
5. Pepeekeo

Table 19. Analysis of 85% Methanol-Insoluble Material in Sugar Crystal

Sugars	Color a*420x10	Meth. Insol. %	Araban %	Xylan %	Glucan %	Polymers % of Meth. Insol.
Lihue	10.6	0.21	0.00240	0.00070	0.034	16.0
Papaaloa	7.1	0.15	0.00250	0.00113	0.044	19.5
Waialua	4.7	0.09	0.00132	0.00050	0.005	5.2
Wailuku	13.4	0.20	0.00192	0.00050	0.017	8.3
Pepeekeo	4.1	0.11	0.00125	0.00050	0.031	28.1

MERCONE CONTINUOUS SUGAR CENTRIFUGAL TESTS COMPLETED

In a cooperative project between Dorr-Oliver, Inc., Waialua, and the HSPA Experiment Station, annual tests have been conducted over a period of four years with the Mercone continuous sugar centrifugal. After each test period the machine has been modified to improve performance. The final series of tests was completed in July and the machine has been returned to the Mainland where further testing will be conducted at an eastern refinery.

In the development work here several problems have been solved and the machine has proved capable of handling commercial massecuites at rates up to 4 tons sugar per hour. The sugar is of acceptable pol and moisture but some crystal breakage occurs. This is a problem with any continuous centrifugal. It has been concluded from working with the machine that it can be designed to keep breakage at such a level that it will not be a serious problem.

SUGAR QUALITY ANALYSES IMPROVED

Development of satisfactory methods for sugar quality analyses has continued as a cooperative project with the California and Hawaiian Sugar Refinery Technical Department. A new procedure for measuring crystal color has resulted and this will probably be recommended as standard for 1961. Because a major factor in color measurement is light scattering rather than absorption, instruments for measuring this have been ordered for both laboratories.

The present filterability test is relatively unsatisfactory; a new pressure method, developed by the C&H staff, will be investigated.

SUCROSE CRYSTALLIZATION RATE STUDIES EXTENDED TO NATURAL SYRUPS

In an example of the effect of purity on crystallization rate, an evaporator syrup of purity 86.33 had a crystallization rate of 393 mg/m^2/min compared with 314 mg/m^2/min for a syrup of 81.86 purity (same sucrose-to-water ratio of 228.2).

The addition of potassium chloride caused a decrease in the rate of crystallization of sucrose from evaporator syrup comparable to that found in pure sucrose solutions. Glucose had no appreciable effect on the crystallization rate from those syrups to which potassium chloride had been added.

The effect of potassium chloride and calcium chloride on the rate of crystallization from sucrose solutions was studied at 55° C. The results were analogous to those found at lower temperatures, namely potassium chloride decreased the rate while calcium chloride increased it.

Time-lapse color movies were made of crystal growth phenomena.

SEPARAN DOES NOT IMPROVE SUGAR QUALITY AT HUTCHINSON

In a three-month factory test at Hutchinson Sugar Company, the juice was treated with Separan AP-30 polyelectrolyte at 2 ppm on alternate two-week periods. Tests in 1959 had shown that this material was an effective clarification aid at Hutchinson and a report from Louisiana indicated it would improve sugar quality also. The results, however, showed no significant effect on either filterability or crystal color. During the test period clarification was good so that Separan was really not needed as a clarification aid; nevertheless, both filtration rate and crystal color were below standard on the average.

INSECT AND RAT CONTROL

ANOMALA QUARANTINE LIFTED

No important developments occurred in the field of entomology during the year. Perhaps the most noteworthy event was the abolition of the Anomala quarantine, by the Director and the Station Council on March 21, in recognition of the fact that the quarantine rules were no longer feasible. The decision did not reflect, nor was it meant to reflect, an improvement in the status of the insect, for Anomala beetles continue to be common in their range of 1959. They seem destined to occupy all the propitious areas of Waialua, and eventually to reach the fields of Kahuku Plantation Company as well.

CANE BORER STATUS UNCHANGED

The status of the other major pest, the cane borer *Rhabdoscelus obscurus* (Boisd.), has also remained unchanged, and it is certain that the situation will not improve until a greater degree of biological control of the pest is brought about. This can be done by shortening the crop period, by substituting hard varieties of cane for the soft or medium-soft canes in general use, or by introducing more efficient natural enemies of the pest than are now present; but, as none of these measures seems to be imminent, *Rhabdoscelus* is expected to remain in status quo.

SOS CALLS BY PLANTATIONS

An excessive number of a collembolan appeared in some upper fields of the Hamakua Coast. The insect turned out to be an *Entomobryia* sp., whose abundance was not unprecedented and need not have caused alarm since the species is always present in cane fields but is not known to harm cane. In this instance, it drew attention because a peak in the population cycle coincided with a period of depressed cane growth, later diagnosed as being due to pollution of the atmosphere by volcanic gases.

Fear was expressed that an exceptionally heavy infestation of the upland armyworm, *Pseudaletia unipuncta* might spread from the lower pastures of the Waimea region to the upper cane fields of the Hamakua Coast. The sequence of events to which the last 10 years have accustomed us was repeated, and *Pseudaletia* was once again stopped short of the cane fields by its efficient parasites. This armyworm remains, nevertheless, a source of serious and justified concern to all the plantations with cattle ranches on the Big Island, and it is certain to continue so until parasites able to work efficiently in the cool uplands are established on the island. The proposed introduction of these parasites is now a project of the State Department of Agriculture and Conservation; but the project is one which deserves our attention, because of its own importance and because of *Pseudaletia's* relationship to other, perhaps only temporarily abeyant, armyworms of the cane fields.

The breeding of mosquitoes in mill waste-water is a problem likely to become acute as housing encroaches into cane lands. The problem is not a difficult one, but it will be solved only with a considerable expenditure of care, money, and manpower.

PLANTATION RAT CONTROL PROGRAMS STUDIED

In the field of rat control, about 80 man-days were spent by the Department in response to plantation calls. In the course of this activity, nine plantations were visited one or more times on the Big Island, three on Kauai, and one on Maui. No major projects were undertaken or recommended, however, except at Hutchinson, Hawaiian Agricultural Company, Hilo Sugar, and The Lihue Plantation Company.

On the first two of these plantations, extensive trapping surveys of their fields were made, in cooperation with the agriculturists. Hutchinson and Hawaiian Agricultural, although they are neighbors, are inhabited by rat populations of dissimilar composition. Both differ from all other plantations in harboring more black rats than Alexandrins, but they differ more importantly from one another in that Norway rats are very abundant at Hawaiian Agricultural whereas they

are almost non-existent at Hutchinson. This explains why Hawaiian Agricultural has always suffered more rat damage than Hutchinson, since the Norway is a far more serious pest of cane than any other species. This knowledge should be advantageously reflected in the future development of the abatement programs on both plantations.

At Hilo Sugar, a cooperative effort was made to eliminate consumption by birds of the baits set out to kill rats. The solution required only simple modifications of the ordinary quonset-hut dispensers employed by the plantation, plus careful placement near a stool of sugar cane or other grass or weeds. A number of modifications of the quonset hut, both old and new, were tried and found equally efficient when properly placed. Some of these are shown in Figures 35 and 36. Hilo Sugar's abatement programs are probably related to the habits and food preferences of *Rattus hawaiiensis*, which is the predominant species on the plantation. A study of this probability is under way and will be intensified in 1961.

Paradoxically, at Lihue the problem concerned is an aftermath of several years of the most intensive and effective rodent control practiced within the industry. The almost complete elimination of the destructive populations of the Norway rat which afflicted Lihue in past years has left the fields open to occupation by other species less susceptible to present methods of control.

The first step in a study now under way is to assess the composition of the new populations now inhabiting the fields. Two species of rat are involved, *Rattus rattus* and *Rattus hawaiiensis*, but it remains to be determined which is the one towards which new control measures should be directed.

New Baits Developed

In work already initiated, the problem of the new populations is being attacked through the development of new baits and bait dispensers. Laboratory testing of potential carriers has continued unabated during the year, but nothing more promising has turned up than the milk-bone dog biscuit which was discovered in 1958. Fortunately, this material appears to be equally palatable to all four rat species and is manufactured in several forms. Lately it has become available in the form of very small oyster biscuits, which should greatly improve the economy of its use in aerial application.

Other possible carriers which were tried in 1960 include rejects of almonds, peanuts, walnuts, and macadamia nuts, plus a long list of commercial pet foods in pellet, kibble, or meal form. Some of the new materials can serve special purposes, but none were found suitable for large-scale plantation use. However, a combination of two well-tried materials did show promise. This is a combination of raw sugar and rolled oats, tightly compressed into cakes of proper size and shape for convenient distribution by hand or machine (Figure 37). In preliminary tests, such cakes have proved considerably more palatable to laboratory rats than Warfarin with rolled oats alone.

Figure 35.

Figure 36.

Modifications of the quonset-hut rolled-oats dispenser which eliminate consumption by birds.

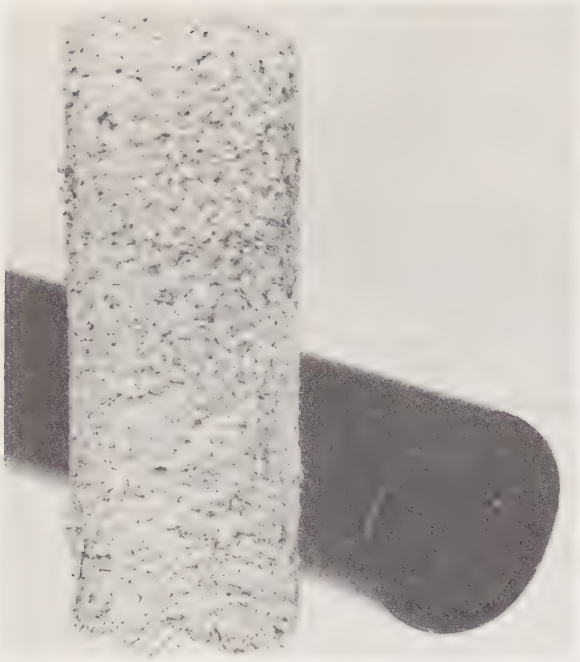


Figure 37. The new rolled-oats raw-sugar cake and a polyethelene tube which protects it from the weather.

The effects of adding hormones to rat food were investigated, using five undescribed hormones obtained through the courtesy of the Worcester Foundation for Biological Research, Massachusetts. Others are forthcoming; but no hormone tested so far warrants the popular assumption of their usefulness as bait additives.

New Bait Dispenser Designed

Research on bait dispensers of greater efficiency than those in current use has resulted in several new designs (Figures 38 and 39). The one known as the "Inverted Tee Dispenser" is simply and cheaply constructed from two lengths of black polyethelene tubing and, on the evidence of preliminary tests, it seems to meet all the requirements of an ideal dispenser: it is light, easy to handle, durable, and provides almost perfect protection from birds and weather. This new dispenser deserves large-scale testing. Its relatively low cost, long life, ease of handling, and effective protection for bait should enable the industry to multiply the number of stations and the amount of bait in present use by a factor out of proportion to the cost of the operation. It is hoped that the new instrument will encourage the plantations to venture beyond their present exclusive adherence to "perimeter control", to the exploration of the very probable advantages of placing bait stations inside the cane fields and in the uncultivated areas adjacent to them, where rats today enjoy a measure of immunity not consistent with good control. The Inverted Tees are not yet available on the market, but 4-inch tubing cut to the proper lengths can be obtained in any quantity, and from this the dispenser can be easily made. The Entomology Department has developed tools and techniques with which a unit can be completed in about five minutes.

KEEPING TRACK OF RATS WITH DYES

An approach to the problems posed by new populations involved the feasibility of coloring the tissues of live rats by means of dyes introduced into their food. Thirteen dyes were tried in combination with milk-bone dog biscuit and rolled oats. Five, Sudan black B, Sudan green, Sudan III, Sudan IV, and Oil Red O, all oil-soluble dyes, colored various tissues intensely and permanently enough for our purposes. Sudan black B proved much superior to the others; when this material, in rolled oats, was fed to laboratory rats for five days their skin and other organs retained a dark bluish tinge for longer than two months. It is planned to color large numbers of rats in the field and, by trapping them at various intervals of time and space, to clarify our understanding of their daily and seasonal movements. This knowledge will be essential to the efficient conduct of control measures.

Figure 38. One of several new rolled-oats dispensers, showing how to apply a ring of mastic-asphalt which protects the grain from moisture and insects.

Figure 39. The "Inverted Tee" bait dispenser.

IRRIGATION

HERRINGBONE SYSTEM OF IRRIGATION STUDIED AT WAIALUA

A part of the Station's coordinated irrigation research program calls for a study to obtain all of the facts about present irrigation methods. This includes: a comparison of present methods or systems; the establishment of facts for analyses leading to improvement of these methods; and the obtaining of base-point costs and water information for evaluation of various overhead irrigation systems.

The irrigation methods under study are: Waialua herringbone and level ditch, on general land slope of over 3 per cent, between 1.5 and 3 per cent, and under 1.5 per cent; continuous long-line, including long flume with plantation outlet, long flume with HSPA outlet, and semi-automatic, on general land slope over 3 per cent.

Plantations cooperating are Waialua, HC&S, Kekaha, Lihue, and McBryde Sugar Company. Other plantations may be requested to participate as the study progresses.

Description of Layout

For each acre, the average layout consists of 169 feet of concrete herringbone flume and 5 feet of irrigation ditch and serves 7,450 feet of furrow. The average distance between furrows is 5.85 feet with the average distance between flume openings 6.40 feet; 134 feet of flume per acre serves two sides of the flume, 35 feet per acre serves one side. Nearly 95 percent of the area is irrigated directly from the flume from 47 flume openings per acre; the remaining 5 per cent of the area is in hapas which are supplied from 4.7 furrow openings per acre. There are 142 feet of field edge per acre with 20 furrows per acre ending there.

The average length of furrow, including short furrows supplied from flume and hapas, is slightly over 150 feet. Over 80 per cent of the furrows are from 120 to 240 feet in length (Figure 40). As used here, furrow length refers to the length of water run.

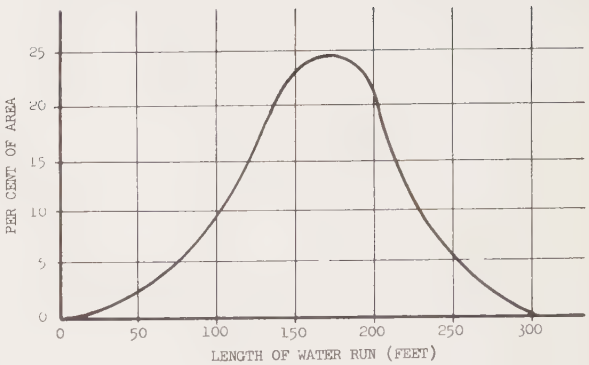


Figure 40.

Cost Generalizations

Total operating costs per acre were distributed as follows: irrigation water, 40 per cent; application of water, 18 per cent; installation, repair, and maintenance of infield irrigation systems, 27 per cent; cost effect of infield irrigation installation on other operations, 3 per cent; and direct supervision, 12 per cent.

The annual operating costs were 22 per cent more per acre than the capital costs.

Infield Water Application

An analysis of water data for approximately 1,000 acres indicates the irrigator applies approximately 196 inches of water per 2-year crop with rainfall supplying an average of 55 useful inches, for a total of 251 inches. The irrigator applied approximately 0.40 inch per day, but if the irrigator applies all water, including useful rainfall, he would apply approximately 0.37 inch per day or 11.3 inches per month. Figure 41 presents the monthly distribution of total water applied by the

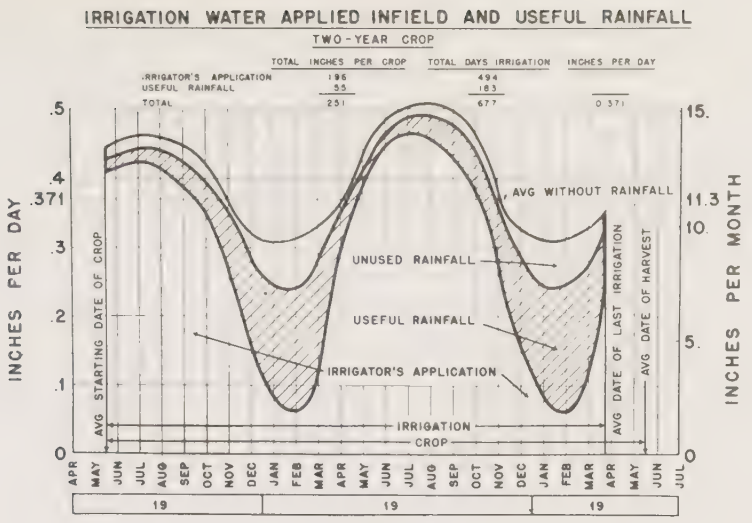


Figure 41.

irrigator, average useful rainfall, and average excess or unused rainfall. The area under the lower curve represents the water applied by the irrigator; the cross-hatched area represents the quantity of useful rainfall; and the area between the top and middle curves represents the quantity of excess rainfall. Excess rainfall is due to rainfall exceeding the moisture-holding capacity of the soil.

With the herringbone system installed on general land slopes over 3 per cent, Waialua's irrigators handle an average flow of approximately 10.4 cubic feet per second (cfs), or 6.7 million gallons per day (mgd). In addition, they perform essentially all infield pushing of cane while irrigating. As this is a combined operation, all costs of applying water include pushing cane.

To apply 98 acre-inches per acre per year (half of the 196 acre-inches per acre for a 2-year crop, Figure 41) with a flow of 10.4 cfs will require 17.88 man-hours per acre per year. Taken into consideration is the daily half-hour lunch period wherein the work is so regulated that irrigation continues during this period. With Waialua's average irrigation interval, the round performance is approximately 16.5 acres per man-day.

RADIATION IMPORTANT IN EVAPOTRANSPIRATION

The lysimeter evapotranspiration projects at HC&S and MASI have been continued with essentially the same instrumentation as in the previous 2-year crop. The three actinometers at HC&S, which give unduly high readings in the summer, are now being checked against the pyrheliometer at Makiki. As soon as the calibrations of the actinometers are corrected, the data of these two projects will be fully analyzed by computer.

The energy budget approach to evapotranspiration has been investigated at Makiki. This approach makes use of the concept of energy conservation. The part of incident radiation that is not reflected or re-radiated back to the atmosphere is called net radiation. The net radiation received at the ground surface is disposed in three ways: heat flux to the soil, heat flux to the air, and the heat of vaporization of water. The heat flux into and out of soil is usually so small that it can be neglected. The energy budget equation can be solved by measuring incident radiation, albedo (reflectivity), net radiation, and the amount of evaporation.

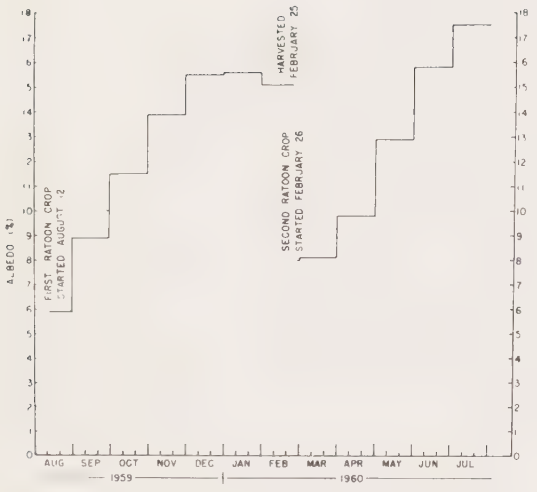


Figure 42. Albedo of a sugar cane field at Makiki.

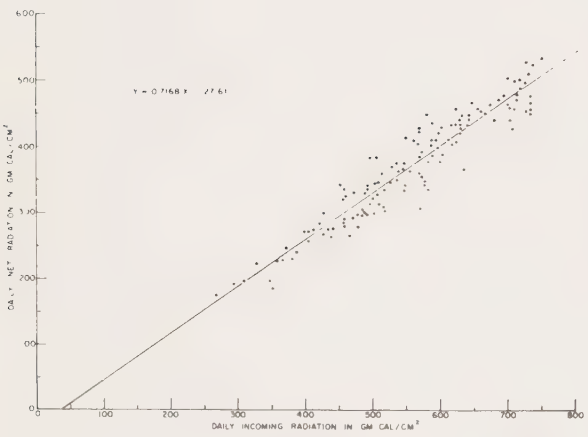


Figure 43. Relation between daily incoming and net radiation at Makiki.

Figure 42 presents the average monthly albedo or reflectivity of a sugar cane field at Makiki from August 1959 to July 1960. The albedo increased with the growing crops from 6 and 8 per cent to 15 and 17 per cent for a well-developed canopy. Although the albedo varies with a number of factors, such as the angle of incidence of incoming radiation, the color of the crop, the darkening effect of rain and the like, for all practical purposes the albedo of a mature cane field may be regarded as 16 per cent.

Figure 43 shows the relationship between total daily incoming and net radiation at Makiki from August 1959 to July 1960. The correlation between the incoming and net radiation was 0.95. On the average, the net radiation was 67 per cent of the incident radiation. This figure agrees very well with observations taken at Ames, Iowa; Centerton, New Jersey; Pineapple Research Institute at Waipio; and other tropical and mid-latitude stations. The back radiation, or the incoming radiation minus reflected and net radiation, was 17 per cent of the incident radiation over a mature cane field.

Comparing the radiation and pan evaporation records at Makiki showed that approximately 85 per cent of the net radiation, or 56 per cent of the incoming radiation, was consumed in evaporation, leaving 15 per cent of the net radiation for heating the air. A preliminary check of the records at the Waipio Substation gives approximately the same percentage figure. Should this radiation-evaporation relationship be further substantiated, the radiation records kept by many plantations may serve as a useful guide for irrigation practice.

LEARNING MORE ABOUT PLANTATION CLIMATES

Weather stations of all the plantations have been located and inspected. The history of present and past stations has been worked out and detailed descriptions of weather stations will be incorporated in a new Key to Weather Stations to be published by the U.S. Weather Bureau.

Thirteen new evaporation stations have been established at Kekaha, Olokele Sugar Company, McBryde, Kohala Sugar Company, Waialua, Waipio Substation, and Lihue Variety Station. New evaporation reporting forms have been issued for plantation use.

A preliminary correlation study of five rainfall stations in the Haiku-uka area of east Maui within a distance of 5 miles indicates that the annual rainfall of any of these stations can be estimated from any other with an average error of about 6 per cent. The average error for estimating monthly rainfall would be in the neighborhood of 10 to 15 per cent.

A new series of mean monthly and annual rainfall maps of the Kilauea area has been constructed on a scale of 1:14,400. Compared with the old PRI-HSPA maps published in 1952, the new maps differ in two respects: (1) in general, the new maps show a higher rainfall, the increase averaging 7 per cent and reaching as high as 13 per cent in places. This is the result of a higher frequency of storms, especially hurricanes, in recent years. (2) The new isohyetal patterns are quite different and presumably more accurate than the old ones due to the addition of many new stations. Not infrequently the new isohyets on the monthly maps differ from the old ones by more than 20 per cent after separating the effect of increased rainfall mentioned above.

CHARTING PLANT ROOTS BY WATER EXTRACTION

In an experiment dealing with the evapotranspiration of sugar cane, a series of gypsum blocks were buried to a depth of 6 feet at intervals of 6 inches. At the time the seed pieces were planted the plot was irrigated so that the soil was brought to maximum field capacity to a depth greater than 6 feet.

As the root systems developed, their extension into new areas was followed by noting when soil moisture was initially extracted progressively downward, as indicated by block readings. The sigmoid curve of Figure 44 shows that the maximum rate of elongation of roots occurred between 40 and 60 days of age.

Repeating the same experiment with ratoon crops showed that at no time during the start of several ratoon crops have the blocks shown that the moisture extraction pattern is different from that of a plant crop.

This would seem to indicate that the old roots are not functioning or, if they are, that they do not extract available moisture from the lower depths in sufficient quantity to register on the gypsum blocks.

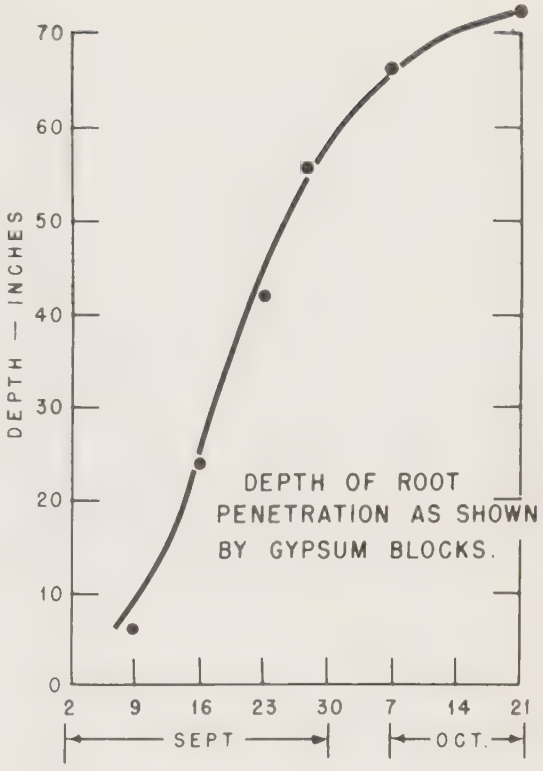


Figure 44.

RELATION OF SOIL MOISTURE TO GROWTH INDICATES PROPER IRRIGATION INTERVAL

When should irrigation be applied to a cane field, and how soon should the next round follow? The answer, of course, is to apply adequate water often enough to obtain the maximum economic return for each irrigation round, measured in terms of final yield. Ideal timing of each round would result in applying water soon enough to prevent impairment of cane growth. Too frequent irrigation not only would involve unnecessary expense but, on some soils, might create an unfavorable root environment. In order to predict optimum timing, soil-moisture changes over time must be measured and the relation of moisture to cane-growth rate must be established.

In measuring soil moisture, gypsum blocks are used because they are sensitive to changes through most of the drying range of the soil. An important advantage is that these instruments are placed

inside the field and readings are taken at the field boundary, allowing continuous recording of soil moisture without requiring that the plantation worker disturb growing cane or force his way through a mat of cane stalks.

To find the effect of soil moisture stress, the rate of elongation of the cane stalks within individual stools was adopted as an indication of growth. The average growth rate of three primary stalks was plotted as a function of the ohm reading of the gypsum block, as shown in Figure 45. In the drier range above 5,000 ohms the distribution of growth-points indicates that moisture is limiting cane growth. Below 5,000 ohms, the points follow no consistent pattern, indicating that factors other than moisture are limiting growth. For optimum irrigation under these conditions, therefore, the objective should be to keep the block readings below 5,000 ohms.

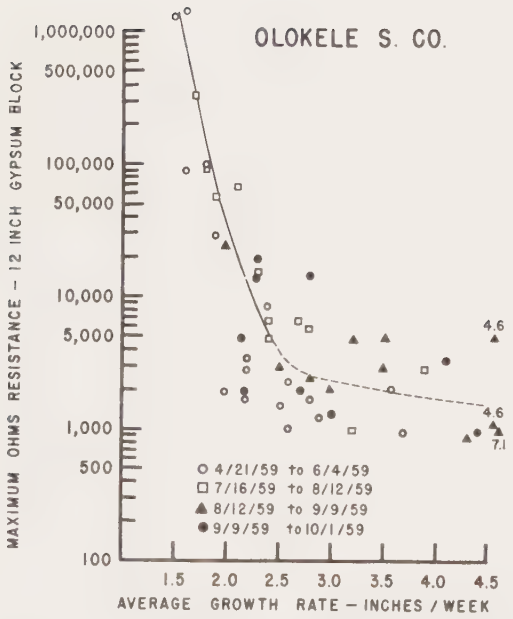
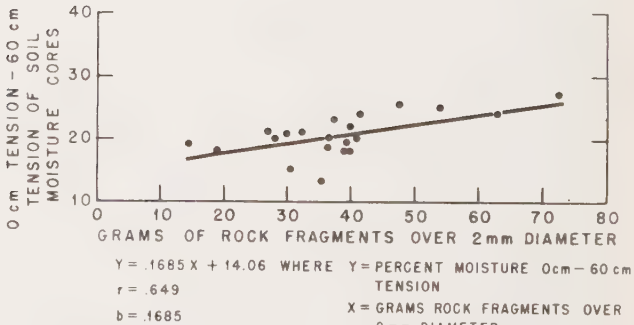


Figure 45. Growth rate of stalks was reduced sharply as gypsum block readings increased above 5000 ohms.

SOIL CONDITIONS AFFECT APPARENT FIELD-MOISTURE CAPACITY

The amount of water remaining in the soil several days following irrigation is commonly designated as field capacity. This value varies widely with soil texture and organic matter content. Field capacity is frequently defined as the moisture held at a tension of ⅓ atmosphere (approximately 330 cm. of water). In reality, this tension is not a constant and has been known to vary from 1/10 to ⅓ atmosphere, as measured on undisturbed soil cores in the laboratory. Regardless of how field capacity is defined, the important practical need is a suitable means of assessing the field-moisture capacity which is attained under actual field conditions following irrigation. A unique situation was encountered on the Ewa soil series at Pioneer Mill Company. Undisturbed cores of this soil were saturated with water and drained under 60-cm. tension. Figure 46 shows that the quantity of water retained in the 0-to 60-cm. tension range increased as the proportion of porous rock fragments increased. This is interpreted to mean that much of the water held in the porous rocks is removed under 60-cm. tension. Moreover, after drainage at this tension, the rocks tend to restrict further downward movement of water in the profile. The apparent field capacity, in this instance, is close to 1/15 atmosphere. Under such circumstances, wider intervals for irrigation may be in order.



CLOSE CORRELATION OF 0 cm TO 60 cm TENSION AND AMOUNT OF ROCK FRAGMENTS SHOWS THAT ROCK PORES CONTAIN MUCH OF THEIR MOISTURE WITHIN THIS RANGE.

Figure 46.

SAMPLING ERRORS ANALYZED IN MASI IRRIGATION EXPERIMENT

Special effort has been made to obtain representative samples for pol ratio analysis. The procedures included: (1) hand-cutting all cane within about 1/40-acre plots, (2) weighing all hand-cut cane with a hydraulic scale which is mounted on a grab-equipped crane, (3) chopping all hand-cut cane with the HC&S prebreaker, and (4) sampling chopped cane for pol ratio analysis by continuous subsampling 10 to 15 times per composite sample from the conveyor belt.

In order to investigate variability in sampling, at least four subsamples were withdrawn from the composite samples for pol ratio analysis in the MASI experiment. Results of a preliminary study on sampling procedure at another site are summarized in Table 20. The coefficient of variation between composite samples within lots or plots of cane was 2.34 per cent. This value is slightly larger than was found for subsamples within composite samples. In other words, approximately the same variability is associated with taking a composite sample as is associated with laboratory analyses. Based on these data, total sampling error is expected to be about 4 per cent.

Table 20. Analysis of Sampling Variation Using Composite Samples

Source of Variation	d.f.	Mean Squares	S.D.	C.V.
Between lots	2	.6912		
Between composites within lots	9	.1122	.3350	2.34%
Between samples within composites	12	.0808	.2843	1.99%

INTAKE RATE IS A FUNCTION OF APPLICATION RATE

During 1960, infiltration studies were completed at Olokele and HC&S. Another study is in progress at Paauhau.

At HC&S, infiltration studies were made on four soil types in the Pulehu and Keahua sections. The plots consisted of field-furrowed land, without special shaping. As expected, a wide range of intake rate values was obtained from 0.45 to 1.25 inches per hour after 80 minutes of application, with an average of 0.78 inch per hour. In more recent studies it has been found that, when water is applied by overhead irrigation, the soil intake rate is a function of application rate. It is concluded that field application rate for these soils should be less than 0.78 inch per hour and very probably near 0.5 inch per hour. Additional work now in progress essentially substantiates this result.

Table 21. Overhead Application Rates on Makaweli and Mahana Silty Clay Soils at Olokele

Soil	Application Rate* (in./hr.)	
	Mean	Range
Makaweli Silty Clay	0.50	0.35–0.70
Mahana Silty Clay	0.29	0.28–0.30

*Application rate is the rate which, if exceeded, would cause run-off; it is the highest application rate which produces perceptible run-off.

The values given in Table 21 were determined from application rate vs. run-off rate curves which have demonstrated that higher intake values are associated with higher application rates of water applied by overhead irrigation. Thus, because one must produce run-off to measure intake rate, this in itself produces a bias which must be adjusted to fix a usable field application rate value.

At Paauhau Sugar Company, a sub-boom was attached to an Ames Boom-O-Rain irrigation unit. The plots were irrigated on normal irrigation rounds when the ground surface was reasonably dry. The results from the first measured round are given in Table 22. With application rate varying from 2.3 to 3.4 inches per hour, the instantaneous intake rate of 60, 80, and 100 minutes was reasonably constant for all plots except No. 5. This was the plot having least slope and receiving the highest application rate, 3.6 inches per hour.

Table 22. Instantaneous Infiltration Rates in Relation to Time of Irrigation

Plot No.	Slope	Instantaneous Infiltration Rates		
		At 60 min.	At 80 min.	At 100 min.
	%	in./hr.	in./hr.	in./hr.
5	5.0	2.87	2.69	2.58
3	7.3	2.46	2.45	2.32
1	7.7	2.33	2.31	2.19
6	11.7	2.47	2.33	2.03
4	12.7	2.11	2.29	2.08
3	12.9	2.36	2.27	2.17
Mean		2.43	2.39	2.23

In Table 23 the intake rate data are grouped into three slope categories. In summary, an increase of 7.5 per cent slope produced a decrease of 0.5 inch per hour in infiltration rate.

Table 23. Slope Affects Infiltration Rate at Paauhau

Slope	Infiltration Rate After 100 Minutes of Irrigation
%	in./hr.
5.0	2.58
7.5	2.26
12.4	2.09

IN-LINE VS. BETWEEN-LINE IRRIGATION COMPARED

On sugar cane soils, where conditions favor reasonably rapid lateral movement of irrigation water, there is interest in studying the relative efficiency of standard "in-line" irrigation vs. "between-line" irrigation (Figure 47).

The irrigation time for each of 18 plots was recorded for nine irrigation rounds. The in-line treatment required 0.99 inch or 25.6 per cent more water for irrigation when compared with the between-line treatment. This experiment will be harvested in 1961.

SURFACE IRRIGATION METHODS EVALUATED

Five plantations have joined with the Station in a cooperative study of irrigation systems presently used. The evaluation will consider water, labor, and other related costs. Climatic factors are being estimated from a measure of evaporation, using American Class A evaporation pans. Water distribution within fields is being measured with Waialua flumes of 100-gpm capacity. All fields under study are being irrigated by an acceptable system of irrigation control; all water supplied (including rainfall) to each field is measured.

Figure 48 shows an example of water distribution by furrow irrigation; during irrigation, 67 per cent of this field received at least 3 inches of water, and 33 per cent of the field received more than 3 inches. This is perhaps the first data which reasonably depict distribution of furrow-irrigation water in a field operation. Preliminary data which have been recently developed indicate that this furrow distribution is a little better than the distribution of at least one overhead irrigation system studied. As these studies progress, it will be possible to determine the uniformity of irrigation in furrow-irrigated fields and compare this uniformity with various overhead systems.

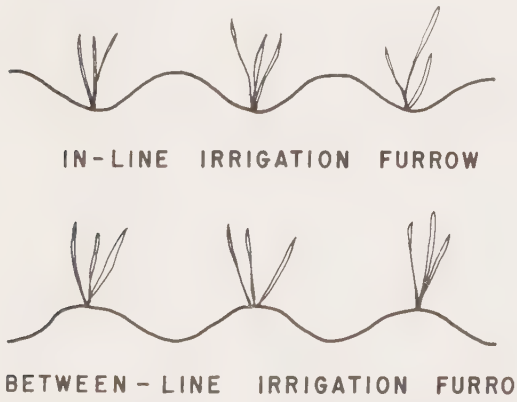


Figure 47. Position of cane line with respect to the irrigation furrow in test at Kahuku Plantation Co.

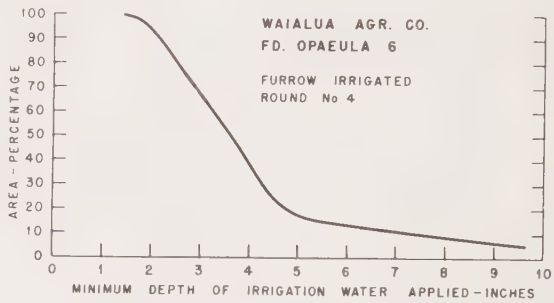


Figure 48. Minimum depth of water applied to various percentage fractions of area under irrigation.

FURROW SHAPE AFFECTS IRRIGATION REQUIREMENTS

Comparison of "V"-shaped vs. "U"-shaped furrows is being made in terms of water required to advance the irrigation stream 200 feet. Twenty irrigation rounds have been applied to this experiment at Waipio. By the end of the 20th round, the "V"-shaped furrow required 8.75 inches less water than the "U"-shaped furrows.

Table 24. Water and Nitrogen Distribution as a Result of Furrow Irrigation

Irrigation Round	Material	Gross to Furrow	Net to 0-100′	Net to 100-200′	Loss inches	Loss lbs./A	Loss %
4	Water (in.)	2.81	1.34	1.18	1.20		43
	N (lbs./A)	95	50	54		43	45
7	Water (in.)	2.46	1.92	1.87	0.56		23
	N (lbs./A)	106	82	82		24	23
14	Water (in.)	2.56	2.70	1.67	0.35		14
	N (lbs./A)	41	44	27		6	13
18	Water (in.)	4.27	4.27	3.19	0.54		13
	N (lbs./A)	112	114	81		15	13
Total (nitrogen)		354	290	244		88	

DISTRIBUTION OF WATER AND NITROGEN IN IRRIGATED FURROWS

Water and fertilizer distribution in furrows was measured each round for one crop within a 3-acre area. Table 24 summarizes the average depth of water and amount of nitrogen applied to 18 furrows in the test area during the 4th, 7th, 14th, and 18th rounds where nitrogen was applied as aqua ammonia in the irrigation water. At a fixed concentration of N in water, there is a high correlation between quantity of water and amount of nitrogen applied. In the irrigation operation, 354 pounds N per acre were applied to furrows, with a resulting loss of 88 pounds per acre. The nitrogen distribution shows 290 pounds per acre applied to Section I as compared to 244 pounds per acre in Section II, giving a differential of 46 pounds per acre. Water applied as irrigation amounted to 87 inches in Section I and 72 inches in Section II. In addition, 20 inches of rain fell during the crop cycle. The field was planted in November 1958 and harvested early in August 1960 at an age of 21 months. Table 25 shows that yield differences are not significant at the 5 per cent level. However, observed differences in nitrogen and water applied show a consistent relationship to yield.

Table 25. Yield of Cane and Sugar in Separate Sections of Furrows (n=9)

Sections	TCA	P%C	TPA
I	118.1	14.6	17.1
II	112.4	14.9	16.6
HSD	ns	ns	ns

LYSIMETER EVAPOTRANSPIRATION AND PAN EVAPORATION QUITE SIMILAR

Sugar cane evapotranspiration and pan evaporation measurements have been made continuously since 1957. Nine lysimeters, all located on Maui, will be harvested in October 1960. For this reason, Table 26 gives evapotranspiration for only one complete year. In this study, evapotranspiration is maximum. Cane in the lysimeters was irrigated frequently to determine maximum water use.

Table 26. Lysimeter Evapotranspiration and Pan Evaporation for One Year (7/1/59 to 6/30/60)

Location	Evapotranspiration	American* Class A Evap. Pan	Ratio
	in./hr.	in./day	
906	0.21	0.25	0.82
405	0.29	0.23	1.25
205	0.26	0.24	1.09
Average	0.25	0.24	1.04

*Pan located at cane-top height.

During the four winter months, November through February 1959, just following ratooning, the evapotranspiration averaged 0.09 inch per day. For April to July 1959, a four-month period when the cane canopy had just closed in, the evapotranspiration to evaporation pan ratio was 0.99. From July 1959 to June 1960, the same ratio was 1.04 (Table 26). Actual evapotranspiration values at three sites at HC&S on Maui show a range in ratio of from 0.82 to 1.25, depending upon location. This variation is believed to be more nearly associated with canopy-lodging characteristics of cane than climatic variations between sites. These

results show that the maximum yearly net water requirements of sugar cane can be reasonably estimated, using a properly placed evaporation pan in sugar cane.

In 1960, an evaporation pan irrigation internal control experiment was installed at Waipio Field L using various pan ratios. This work was initiated to further develop an understanding of the potential use of climatic data in irrigation practice.

HSPA MOLDED OUTLET ADOPTED BY McBRYDE

During 1959 McBryde re-examined all outlets available for metal flumes and revived an interest in the HSPA molded outlet. In November 1959, a 22-acre test plot, using this outlet and certain minor flume changes, was installed at McBryde to test the equipment and its influence on the irrigator performance.

On the basis of observations and initial testing, McBryde decided to convert their existing sock outlet flumes to the HSPA outlet and also use this outlet for all new flume installations. They also made arrangements to have the outlet mass-produced by purchasing an injection mold. The material selected for initial production is a black vinyl known commercially as Geon No. 8849. The outlet is available to other plantations in substantial quantities.

To aid in the proper installation of this type of outlet, a power-operated combination punch and forming die has been designed, fabricated, and mounted on a light trailer (Figure 49). The hole is punched and the flume is flattened around the hole as a single operation. This unit can be taken to the job and used for conversion of existing flume to the HSPA outlet or can be used for a new flume installation.

This outlet will be analyzed to determine its potential as a means of improving irrigation systems and as a means of improving irrigator performance using the long-line system. Also, there are several test sections in use with the outlets on the sides of metal flume for herringbone systems.

Figure 49. Flume punch press forming HSPA outlet hole.

SEMI-PERMANENT OVERHEAD IRRIGATION SYSTEMS UNDER TEST

The maintenance and development for the 14-acre Shur-Rane Sequa-Matic, semi-permanent system at HC&S has continued. Improvements have been made to partially or totally correct troubles which have developed. Cane lodged on the lateral lines presents a unique maintenance problem. A stretching device was developed as a means of disassemble and reassemble at the joints, making lateral repairs possible without removing the pipe.

Analysis of the maintenance records for the first six months showed a total of 143 malfunctions observed and recorded. Sprinklers skipping during an irrigation accounted for 32 per cent of the malfunctions, clogged risers and sprinklers for 20 per cent, and leaning, poorly supported risers for 14 per cent.

A 100-pound per acre application of nitrogen was applied by pumping a urea solution into the main pipeline. Observations were made on the sprinkler discharge and concentration at 43 sprinklers located randomly throughout the test plot. The results showed very little correlation between sprinkler discharge and position, and between nitrogen application and position. This indicated that the fertilizer solution was well distributed throughout the system. Using tolerance limits for 90 per cent of the sprinkler heads, with a confidence of 95 per cent, the expected variation of total fertilizer delivered to individual sprinklers is plus or minus 24 per cent.

A grid-type system of 15 rain gauges has been installed in the field and is being used to check out the predicted uniformity of coverage.

ADAPTING OVERHEAD IRRIGATION EQUIPMENT TO HAWAIIAN CONDITIONS

To assist in achieving the full potential from an Ames Boom-O-Rain system of overhead irrigation, the water distribution characteristics of a late model unit were determined at Kilauea. Results show that under the operating conditions at Kilauea a two-hour set provides (1) a minimum application of 2 inches on 60 per cent of the field, (2) an application of 1.56 inches on 20 per cent of the field, and (3) an application of 0.84 to 1.56 inches on the remaining 20 per cent of the field. An economic evaluation of this type of equipment is also being made.

As a further study of the installation and operation of a semi-permanent, solid-type overhead irrigation system, cooperating studies were initiated with Kahuku on the installation of a 14-acre test using Farmland Irrigation Company equipment. Buckner 860P sprinklers with 5/32-inch nozzles operating at 45 psi are used with a 30×50 triangular spacing. The area is irrigated by means of eight 2-inch lateral or feeder lines with an automatic valve for each line. A timer controls the system and provides completely automatic irrigation. This system attains the same results as are obtained with the Shur-Rane Sequa-Matic, but uses more nearly standard equipment. The valves can also be manually operated.

LEVEL DITCHES CLEANED MECHANICALLY

The original experimental work for cleaning level ditches mechanically used a garden tractor as a prime mover. A single high-speed rotary disc with radial fins appeared to be a satisfactory means for removing loose soil, wet or dry, with or without weeds in the ditch.

To improve productivity and ease of operation, a double-disc assembly was designed, fabricated, and attached to the front of a light-duty track-type tractor. The two 28-inch diameter discs were rotated at a tip speed of 3,480 feet per minute. The over-all width of the two discs was 48 inches. The tractor was widened to a 72-inch gauge so as to straddle the ditch (Figure 50). Preliminary time studies showed that the machine cleaned level ditches at a rate of 28 feet per minute and was equivalent to 14 men with shovels.

The drawings for this attachment have been completely revised to give a more rugged unit, and the spread of the two 25-inch diameter discs has been reduced to 42 inches. Minimum disc speed is to be determined.

Figure 50. A ditch after one pass of double-disc cleaner.

MECHANIZATION

PROTOTYPE HARVESTER TESTED IN FIELD

The HSPA seed cane harvester was moved to HC&S in November 1959 for field testing and development in cutting seed cane growing in irrigated furrows. The ground knife was dropped several inches and the gauge wheel brackets were raised several inches. Several other small changes were made based on assumed requirements for cutting in furrows. Field tests were initiated in Field No. 720, first ratoon 50–7209 cane. This cane was only five months old but, because of the vigorous growth and sandy soil, was lodged almost 100 per cent. The down cane laid close to the ground and was lodged into adjacent rows. The gathering assembly on the machine was totally inadequate for these conditions. The cutting conveyor assembly was returned to the shop for major changes to the gathering assembly as follows:

1. A vertical pickup chain was added to each side, the lugs of which would contact the ground and get under the blanket of cane.
2. The gathering chains were relocated so as to take the cane away from the pickup chains and also to provide an even flow to the topper.
3. A short lay-down type of belt was added to deliver the cane from the gathering chains to the topper.
4. Changes were made to the topping assembly to give more clearance for discharge of tops and a more positive discharge.
5. Slats were added to the conveyor deck chains to give a more positive conveyor flow.
6. A higher-torque oil motor was installed on the ground knife drive.

The machine was returned to the field with substantially improved results. After a few minor changes to the gathering assembly, the rpm of the No. 1 detrashing fan was increased with resulting improvement in the detrashing.

Four bins each of hand-cut and machine-cut seed of 50–7209 were examined: seed pieces were counted; eyes were counted and checked for damage; trash, including tops, was weighed separately. A summary of the results follows:

	Hand-cut	Machine-cut
Average gross weight of bin, pounds	2,000	1,550
Average trash, pounds	13.2 (0.6%)	72 (4.6%)
Number of pieces, average per bin	2,267	1,633
Number of eyes, average per bin	8,223	5,718
Eye damage, average per bin	251 (3.05%)	631 (11.02%)

For a further check of eye damage, the seed was planted in tagged blocks in Field 604, and one month later a germination test was made by measuring all blank spaces, 3, 5, 7 feet and longer, with the following results:

	Hand-cut		Machine-cut	
	Feet	Avg. %	Feet	Avg. %
Total feet of line	8,123		8,049	
Blank spaces:				
3 feet and longer	1,492	18.4	1,989	23.6
5 feet and longer	390	4.8	595	7.4
7 feet and longer	140	1.7	280	3.5

CANE PUSHBACK MACHINES IN OPERATION

The initial work consisted of a 9-foot mechanized bar mounted on the side of a D-4 tractor. A cooperative project with Kilauea Sugar Company used a bar of this same design which included an extension frame whereby the operator can reach out an additional 5 feet (Figure 51). HC&S further increased the versatility with a pushback bar across the front and extending to the right-hand side of a light track-type tractor. The right-hand track travels over pushed cane, therefore the unit pushes cane by traveling alongside the flume or ditch.

Figure 51. Cane pushback bar mounted on 5-foot travel carriage.

As a final step in the over-all development for mechanical pushback, a 9-foot bar was designed, fabricated, and tested on a light-duty prime mover which straddles the flume or ditch. Such a unit can also push along roadsides. This development resulted in the conclusion that a straddle prime mover should be equipped with two bars, right and left. This adds versatility plus avoiding any trampling down of cane by a tractor track.

NEW SEED CANE HARVESTER IN OPERATION AT KOHALA

A new machine was built by Hawaiian Equipment Company, Hilo, for Kohala from drawings provided by the HSPA. The design was based on the design and development of the original HSPA machine. A TD-15 tractor is used for the prime mover, and the cutting conveyor assembly is located on the right-hand side. A cross-load conveyor carries the cut cane across the back of the tractor and loads a storage-transload conveyor which has a 2-ton capacity. This is in lieu of the bin rack on the original machine. The storage-conveyor assembly counterbalances part of the weight of the cutting-conveyor assembly, thereby reducing the load on the outboard wheel (Figures 52 and 53).

The 2-ton storage-transload conveyor was devised as part of a system originated by Kohala which substantially reduces the capital cost of a complete seed-cutting and handling system. The cut seed is loaded directly into a four-compartment watertight-body dump truck (Figure 54). Hot-water treatment is accomplished in the truck body at an automatic station designed and developed by Kohala. Each compartment fills one bulk bin at the plant field for forklift transfer to the planting machine. One fringe benefit of this system is that there is no forklift in the seed-cutting area.

When this machine was delivered in January 1960, the only cane available for cutting as seed of the required variety 49–5 was recumbent. The gathering assembly on this new machine did not cope with this problem. A new gathering assembly was designed and installed on the machine in April 1960, with immediate and satisfactory results. The

Figure 52. Front view of Kohala seed cane harvester showing gathering-topping assembly on the cutting conveyor and the storage-transload conveyor in the unload position.

Figure 53. Seed as cut and detrashed by Kohala seed cane harvester.

major difference between this gathering assembly and the revised assembly on the HSPA machine is that the gathering chains are extended and attached to the topper. The gathering chains convey the stalks into the topper, and a guide around the lug tips of the left-hand gathering chain disposes of the severed tops.

Trouble in the storage transload-conveyor was handled by extending the primary conveyor so as to eliminate the conveyor extension. The cross-flow cutting assembly, which cuts the flow of cane into 18-inch lengths, was too light for production operation and is being replaced by a heavier, slower-speed assembly based on the design of the cross-flow cutter used in the cut-convey-load machine. Larger oil motors are being installed on the two detrashing fans to increase detrashing.

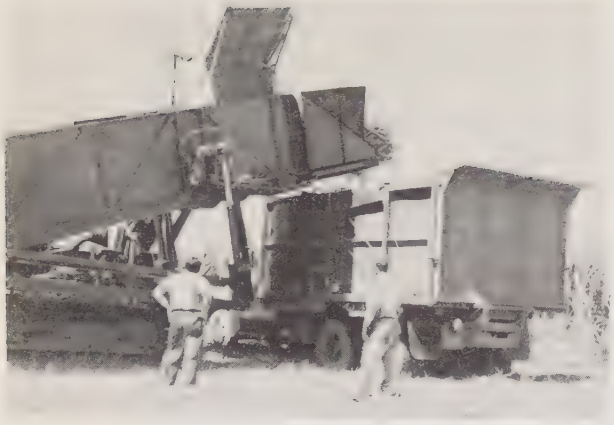


Figure 54. Transferring seed to treatment dump truck at Kohala.

SEED CANE HARVESTER DESIGNED FOR HC&S

HC&S is building a direct-mounted machine described as follows:

1. The prime mover is a J. I. Case 1010 tractor. The engine is relocated over the right-hand track and the operator is over the left-hand track. By adding two rollers each track assembly has been extended to eight rollers.

2. The cutting-conveyor assembly is located between the tracks, extending to the front and with a storage bin at the rear of the tractor. The design of the gathering-topping assembly is based on the assembly in use at Kohala. The conveyor is 2 feet wide at the bottom and flares to 3 feet at the top. The cross-flow cutter is of heavy duty design, based on design of the cutter on the cut-convey-load machine. The one-ton capacity storage bin is supported from the upper end of the conveyor. One blast of air is used for the detrashing.

3. There is a 2:1 reduction from the engine to the transmission. This was done to reduce travel speed to one-half standard. The cutting conveyor is being set up for a cutting speed of 0.80 mph.

4. The conveyor assembly and the ground knife are driven by mechanical drives. The topper, detrashing fan, and gathering assembly are driven by oil motors. Each side of the gathering assembly is driven by an oil motor as a means of varying the speed of the pickup and gathering chains to compensate for the direction of lay of the down cane. It is expected that this will be a means of delivering cane to the topper in a fairly erect position for good topping. Good topping has proved to be a major factor in good detrashing.

HC&S is building this machine and field testing will start by early November. Revised drawings will be available soon thereafter.

IMPROVEMENT OF DISC LINE RESHAPER

Several things have been tried in cooperation with Oahu Sugar Company to improve disc line reshaper for certain conditions:

1. Use of sheet Rulon and sprayable and sheet Teflon for stubble shavers. The service proved to be more severe than was expected. It appeared to be practical to keep a scouring material on the upper one-half or two-thirds of each wing. This gives better results in damp, sticky conditions.

2. Two discs were sprayed with Emeralon (a Teflon derivative). Preliminary results indicate that the soil pressure across the disc is not great enough to cause scouring even with this material.

3. One stubble shaver has been assembled using 16-inch left-hand and right-hand moldboard plow bottoms. The initial results show advantages (Figure 55).

4. A 12-inch double moldboard is being tried for replant furrows.

DISC-TYPE STUBBLE SHAVER TRIED

The disc-type free-cutting type of knife does a

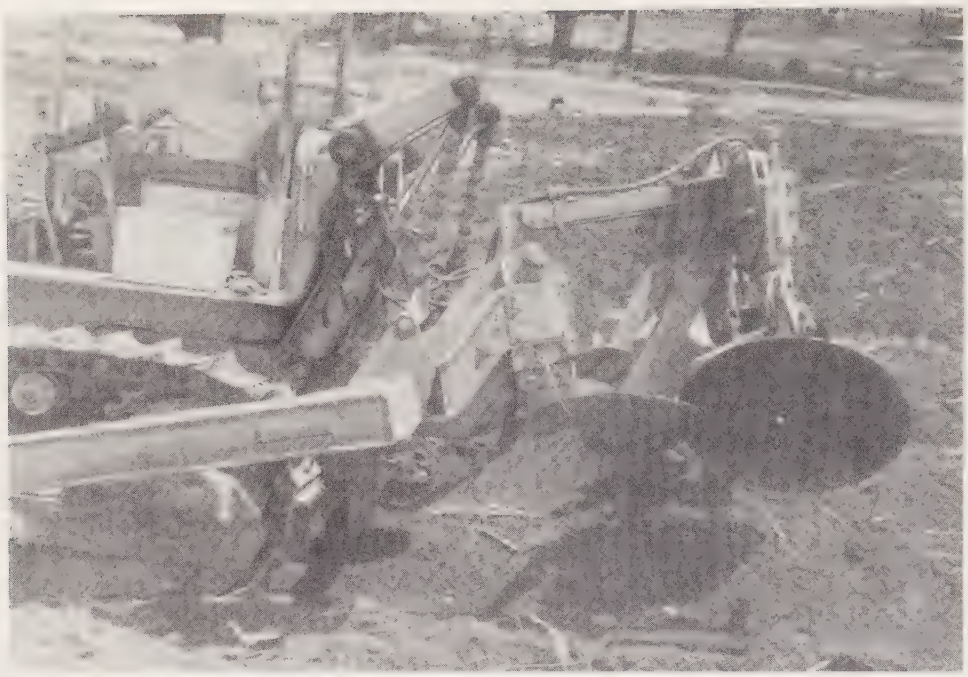


Figure 55. Line-reshaper stubble-shaver with right- and left-hand plow bottoms.

good job of stubble shaving. A major disadvantage of using this principle for stubble shaving is the relatively high consumption of horsepower, since the knife is cutting soil as well as stools and the torque is necessarily high.

As a possible means of maintaining quality work and reducing horsepower requirements, a 30-inch diameter flat-rim wheel was mounted so that the axis of the wheel was parallel with the furrow or direction of travel (Figure 56). The leading edge of the band-type rim was sharp or notched and sharpened. Experimental work had been done with this type of cutting element in the Philippines.

Initial operation showed certain advantages for this kind of knife. In addition to the stubble cutting, there is a partial line-reshaping job accomplished. Dust was a problem in dry conditions, but with hooding and slower speeds this may be controllable. The preliminary indication, however, was that power requirement would not be less than the standard disc-type knife.

LILIKO CUTTER-RAKE PERFORMS AT PIONEER

Pioneer Mill set up a liliko cutter-rake combination using available hydraulic equipment in which they reduced the cutting-knife tip speed to 1,570 feet per minute as compared to the previous 3,000 feet per minute. This proved to be an adequate cutting speed for this type of cutting. It was also found that the resistance to the turning of the knife was about the same as for higher speeds. So Pioneer demonstrated a means of reducing the horsepower required for stubble shaving with a rotary ground-cutting type of knife. It is expected that this will reflect also in reduction of horsepower on cane harvesters.

LILIKO PICKUP PRINCIPLES STILL UNDER STUDY

The spiked-wheel principle for picking up loose, short pieces of cane proved to be an effective means for picking up liliko except in sticky and wet conditions. Since it could not be used in damp

Figure 56. Wheel-type stubble-shaver being tested.

or wet weather, the cost of the machine and the operation could not be justified. HC&S has continued work along this principle by using a series of sticker chains for picking up and elevating the cane into the hopper. This has proved to be a better all-weather unit and appears to have potential.

To continue the exploration of satisfactory methods for picking up loose liliko with a range of weather conditions, a one-row experimental unit using a spring-tine pickup principle has been designed and fabricated. This unit will be field tested to determine the potential of this principle.

STREAMLINED CUT-CONVEY-LOAD HARVESTER DEVELOPED

The minimum design of a cut-load harvester has been accomplished, based on the concept of cutting the flow into manageable or easily-conveyable lengths as it is picked up and lifted off the ground. A standard rotary ground-cutting knife, a side-trim knife for cutting the division, four pickup tines, and two short conveyor chains are used. Immediately back of the outside pickup tines is a 7-inch O.D. backup roll against which a 30-inch tip diameter, double-sickle bar-type cross-flow cutter cuts. There is no conveyor or deck. The width of assembly or maximum width of cut is 6 feet (Figures 57 and 58).

The flow, after being cut into 15- to 18-inch lengths, drops onto a higher-speed, 24-inch wide cross-load conveyor which carries the cane up and drops it into the transport traveling alongside. The assembly was set up to cut furrow-irrigated cane. No detrashing is provided, however trash fines and soil drop back to the ground from the pickup tines (Figure 59).

The two-way cut-load prime mover is being used to carry and power this new assembly. The pickup and cutting speeds are set for the 0.75 mph. low-gear speed. It is estimated that on a second machine a ground speed of approximately 1.5 mph will be used. A more suitable prime mover is required to estimate potential production with minimum liliko.

Figure 57. Cut-convey-load harvester operating in 90 net tons per acre cane.

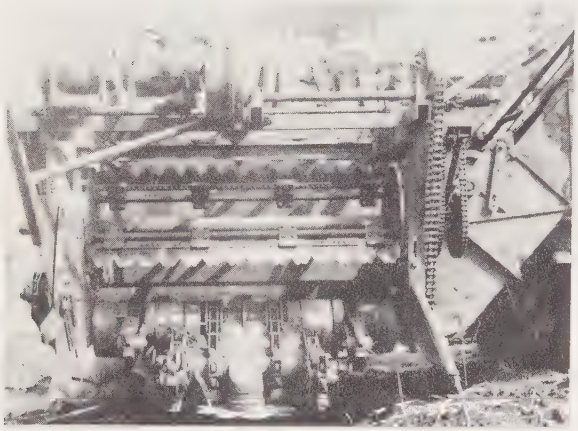


Figure 58. Pickup-cutting assembly of the cut-convey-load harvester.

Figure 59. Sugar cane cut and loaded by cut-convey-load harvester.

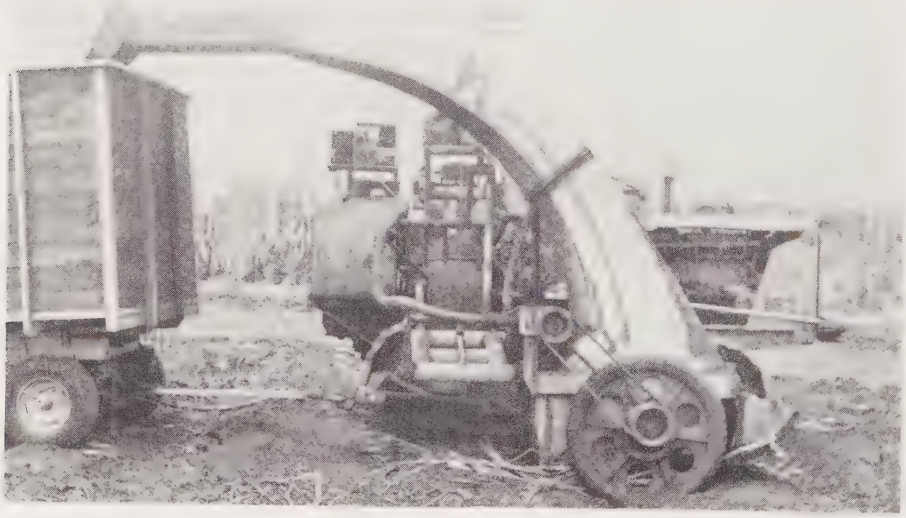


Figure 60. Side view of cut-throw-load harvester showing location of outside gauge wheel.

This experimental machine is being used principally for development of the pickup for minimum liliko and feed of the flow to the cross-flow cutter. The self-feeding characteristic of the cross-flow cutter is adequate as an assist to the pickup tines to maintain a uniform flow into the machine for burned cane and a ground speed of 0.75 mph. However, the indication has been that a more positive feed is desirable and will be necessary for a higher ground speed and in unburned cane. A floating feed-drum with disappearing tines is being tested, also a rearrangement of pickup tines and short conveyor chains for more complete pickup and more positive flow.

Preliminary data are as follows:

Travel speed	0.75 mph
Production rate while cutting	1 ton/min.
Trash, with good cane burn (tops, leaves, soil)	3.91%
Average power consumption (exclusive of travel)	0.70 to 1.0 hp/ton/hr.
Liliko (plant-irrigated cane)	1.0 to 2.5 tons/ac., 1 to 5%
Condition of liliko	average
Surface rocks	some tolerance
Lengths of cane in load:	

Length in inches	Per cent of total
Under 8	12.95
8 to 14	34.16
15 to 30	49.67
31 to 48	2.46
49 to 60	0.76

Load density	16.2 lbs/cu. ft.
Detrashing potential	Good

CUT-THROW-LOAD HARVESTER TESTED AT HC&S

Field testing and development of this experimental unit was initiated in 1959. The principle of this machine is based on the flail-knife type of forage-harvester. The direct cut-throw principle was selected for initial work rather than the cut-blow arrangement since the cut-throw gave the simplest machine with the fewest moving parts. Also, data from forage crop operation indicated lower power consumption with the cut-throw. The 24-inch tip diameter forage-harvester did not allow for a great enough depth of cut, therefore this unit was designed on the basis of a 44-inch tip diameter and a 6-foot width of cut (Figure 60).

The rotor assembly is mounted so that it has complete flexibility for ground follow. The major change before test operation this year was that the small-gauge wheels which followed the rotor were replaced with a large-diameter gauge wheel at each end of the rotor. The O. D. of the gauge wheels is approximately the same as the tip diameter of the rotor while cutting. With this arrangement the cutting could be across furrows with better results than had been possible in attempting to cut with the furrows.

Enough test data have been accumulated for preliminary conclusions:

Travel speed	0.5 mph
Production rate while cutting	0.5 ton/min.
Average power consumption (exclusive of travel)	2.1 to 2.6 hp/ton/hr.
Liliko (irrigated cane)	17 to 21 tons/ac.
	15 to 25%
Condition of liliko	average
Soil in cane	10 x hand cut
Sucrose losses	none
Allowable time before milling	6 hrs.!
Load density	25 lbs./cu. ft.
Surface rocks	no tolerance
Detrashing potential	none

It can be assumed that the liliko could be reduced by flat culture as long as the surface is free of ridges and indentations. However, there would be more damage to the liliko because at the present time most of the liliko is in the bottom of the furrow and protected.

All the field testing of this unit has been at HC&S. Most of the cut cane has been delivered to their pilot pumping plant which delivers cane to the Paia Mill. Because of the range of fineness of this material it has been desirable to run this material through a prebreaker before feeding into the pipeline system. Also, indications have been that some changes would be required in the milling train in order to feed this fine material effectively.

In conclusion, it can be stated that this is one principle for harvesting sugar cane. The advisability of designing and building a production unit based on the data procured with this experimental unit can be based on comparable data of another principle. Results with this unit indicate that a secondary harvest system would be required to follow this operation since the cane left on the ground exceeds what can be considered a liliko operation.

WEIGHING FIELD EXPERIMENTAL CANE

A Martin-Decker hydraulic remote-reading scale has been adapted for weighing cane with the Waipio Substation hydraulic grab. Since the grab is held shut hydraulically, the load cell could be

located between the end of the lift line and the grab.

The need for a similar means to weigh cane in a wire-rope closing grab has been requested to make possible the use of a standard harvest grab for weighing cane in the field. Since the closing line holds the grab closed and lifts it, it is necessary that the load on the closing line be weighed or that the grab be held closed by some other means. Work in past years had explored various ways for holding a wire-rope closing grab shut. Several of the better ideas were tried and were eliminated after testing.

The discussion always came back to the possibility of weighing the load on the closing line. As a means of doing this, a hand-pump hydraulically-actuated clamp device was designed which rides on the closing line near the cab of the loader. The load cell or dynamometer, which is dead-ended to the frame of the machine, is attached to this clamp device. After the clamp device takes hold of the wire rope, by working the hand pump the operator releases the closing-line drum and the full load is registered on the load cell or dynamometer. This arrangement provides maximum safety for everyone and is a means of taking direct reading (Figure 61).

Pioneer has fabricated and assembled one of these devices from the drawings. The initial testing has given satisfactory results and appears to be a means whereby any plantation can weigh experimental cane in the field using a standard loading machine and standard grab. About 15 seconds are required to actuate and release the clamp device. With the operator and the weight recorder working together, the total time for weighing a grab load of cane should not exceed 30 seconds.

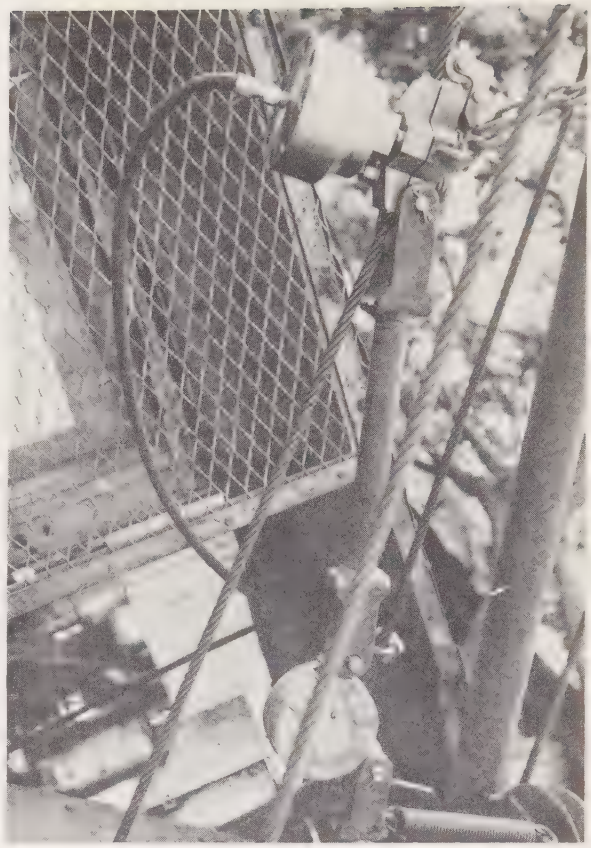


Figure 61. Hydraulic clamp and dynamometer for weighing cane in a wire-rope closing grab.

HARVEST CANE CORE-SAMPLER SHOWS MERIT

A cane core-sampler has proved to be a practical means of sampling a truck load of harvest cane for determination of tare and juice quality. The development of this machine resulted in some simplification since it was found that the outer tube which protected the inner rotating cutting tube could be eliminated. So, in principle, the final design of this unit consists of a 10-inch I. D. tube with saw-type teeth on its tip which rotates at 100 rpm and is pushed into and is withdrawn from the load of cane. The standard sample is 10 inches in diameter by 5 feet long and normally weighs from 40 to 50 pounds. After the tube is withdrawn from the load of cane, the sample is ejected and analyzed.

Puna ran a series of tests as outlined by the Statistical Department to compare this method of sampling with their standard hand-stripping procedure. An analysis of the data showed that the reliability was the same for both systems. The statistician pointed out that a sure procedure for increasing the total reliability would be to increase the number of samples. This machine is a convenient means of doing this and it is estimated that, with one-third the manpower for hand-stripping, the number of samples could be doubled. The size of core sample is about 1/20 the sample used for hand-stripping.

Figure 62. Completion of side-trimming a load of cane.

LOADED CANE TRUCKS TRIMMED MECHANICALLY

A device to trim loads of cane was developed for Lihue consisting of a 12-foot long double-sickle-bar assembly mounted vertically on the side of a D-4 tractor. A light bulldozer blade is mounted on the front of the tractor and the sickle-bar assembly is located so that the trimmed-off pieces of cane drop ahead of this blade. The trimmed-off stalks are then easily pushed into a pile; after adequate accumulation this cane can be loaded into a transport for delivery to the mill (Figure 62).

In actual operation the tractor is kept stationary with the sickle assembly operating and the truck is moved slowly past. This has proved to be a safe and expedient operation. Some thinking has been done relative to a station through which trucks would pass without stopping. There could be an electrically powered sickle-bar assembly on each side of a gantry-type frame. The truck driver would start and stop this operation and would trim his own load.

TRACTION AND MOBILITY— WHEELS COMPARED WITH TRACKS

This basic work was initiated with two objectives: (1) to determine a standard procedure for comparing the traction and mobility of two machines or vehicles directly, and (2) to determine a procedure for estimating the effectiveness of a vehicle or machine in definable field conditions using the specifications of the machine or vehicle.

The first phase was a direct comparison between a track-type tractor and a unit equipped with 36-inch diameter by 20-inch wide low pressure Terra-Tires with Chevron tread. Even though the Terra-Tire is a substantial improvement for infield work over standard low-pressure tires, the track principle gave the best all-around results. However, in most situations the low-pressure Terra-Tire approached the results of the track.

Conclusions drawn from the preliminary data are as follows:

The advantages of endless track: (1) more traction for given vehicle weight, (2) better flotation,

(3) less motion-resistance on soft soil, (4) less soil damage, (5) less affected by slippery conditions, (6) better stability on side slopes.

Advantages of the Terra-Tires: (1) less motion-resistance on hard surfaces, (2) less damage to road surfaces, (3) greater range of travel speeds.

The trend of the data indicates that with the same unit-pressure between the tire and the soil, and the track and the soil, most of the advantages for the track would be eliminated; however, for most types of machines this would require a prohibitive number of tires. The steel track loses its advantages as the soil becomes drier or firmer.

For the second phase of the work, two different approaches were investigated. First was the approach by M. G. Bekker, who had assembled equations which take into consideration certain specifications of the vehicle or machine together with test data obtained in the field by means of thrust- and sinkage-test plates. Data were obtained for Bekker's equations and the results using these equations were compared with the direct results of the vehicle testing. The preliminary data indicate that Bekker's approach is not a practical means for determining the traction and mobility of a vehicle. However, such may be of value in analyzing qualitatively anticipated design changes for either track or wheel vehicles.

The cone penetrometer, as developed by the U.S. Army Corps of Engineres, was used for experiments. This is convenient equipment to work with and has accuracy adequate for practical field requirements. There is cooperative work in progress between the Corps of Engineers and the Station Agronomy Department which will accumulate enough data from which conclusions can be drawn, and this work can augment the work of the Field Engineering Department on traction and mobility (Figure 63).

Figure 63. Using a Corps of Engineers cone penetrometer.

HARVESTING PROBLEMS STUDIED FOR HILO-HAMAKUA COAST

Harvesting methods on the Hilo-Hamakua Coast have been the subject of a cooperative study with C. Brewer and Company, Ltd., and Theo. H. Davies & Co., Ltd. Except for liliko sampling at Hilo Sugar, all work was in cooperation with Pepeekeo and Laupahoehoe Sugar Company.

The first step was to obtain operating and capital costs of present harvesting methods. The second step was to determine the costs of liliko left and of juice lost from handling and cleaning, the effect of trash on hauling costs, and the cost effect of field damage. To pin down these costs, extensive field tests were conducted during the fall of 1959 and the spring of 1960.

Field surveys showed that approximately 85 per cent of the terrain is such that the cutter-transport or pickup-transport could be used. Approximately 70 per cent of the time the soil is sufficiently dry to take road transports into the field, but only in areas where the terrain is such that the cutter-transport or pickup-transport could be used.

Capital and Operating Costs:

Considering only the costs on the books, without considering costs of sugar losses, trash handling, and field damage, the following general conclusions are possible:

1. Use of the pickup-transport following V-cutting, as a substitute for rake-windrowing, infield loading and buggying to the roadside, has a slight economic advantage.

2. Use of the cutter-transport (redesigned) with road trucks taken infield is considerably more expensive than using the V-cutter, windrowing by rake, and loading directly to road trucks taken infield.

3. Taking road transports infield, when soil moisture conditions permit, has a decided economic advantage.

Sugar Losses from Harvesting and Handling:

The following conclusions are drawn from a study of pol losses:

1. No dollar credit may be assigned to any single method of harvesting as no significant differences exist in pol losses among the various methods studied.

2. Total pol losses from standing uncut field cane through the cleaner are about 10 per cent of the pol in standing uncut field cane. This pol loss amounts to a loss of net income before taxes of over $100 per acre harvested.

Liliko Losses:

1. In comparing the three basic harvesting methods, V-cutting with rake-windrowing, V-cutting with pickup-transport, and cutter-transport, all without liliko rakes, no dollar credit for decreased liliko left in the field may be assigned to any single method. The amount left is approximately 8 tons of liliko per acre.

2. Liliko rakes, following the harvest methods of V-cutting with rake-windrowing and cutter-transport, result in a reduction of approximately 3 tons of liliko per acre. Eight tons of liliko per acre are too much to leave behind but the liliko rake, as used, is not an economical way of reducing this amount.

3. Push-rake harvesting without liliko rakes leaves approximately 5 to 6 tons of liliko per acre. or approximately the same as the other harvesting methods followed by liliko rakes. It appears that when the push rake makes second and third passes in harvesting it accomplishes approximately the same results as does the liliko rake.

Trash Costs:

1. There are very few differences, if any, in the amount of trash delivered to the unloading station for the three methods of harvesting and handling employed at Pepeekeo.

2. The percentage of total trash, under all operating conditions, is significantly lower at Pepeekeo than at Laupahoehoe, probably due to differences in soil.

3. Under wet conditions at Laupahoehoe, regardless of the degree of soil moisture, the additional handling required to buggy to the roadside substantially increases the amount of soil incorporated with the cane and leafy trash (Figure 64).

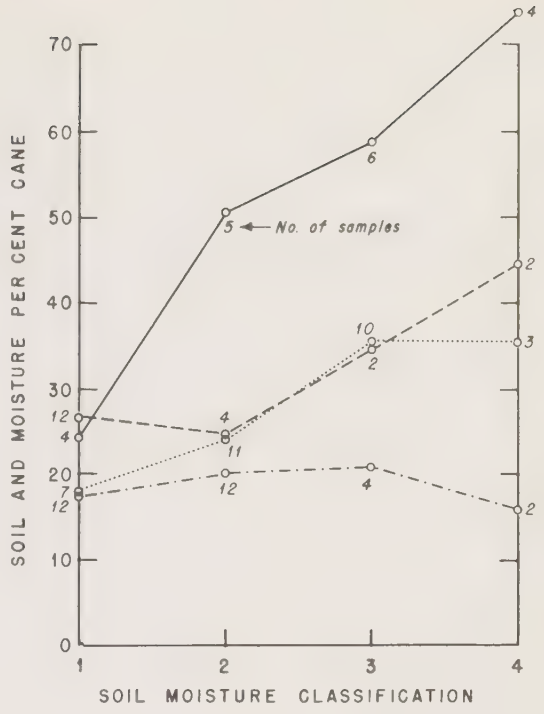


Figure 64. Soil and moisture (mud) delivered to unloading station for various harvesting and handling methods.

4. Particularly under wet conditions, the cutter-transport has a decided advantage over the V-cutter with rake-windrowing. This is attributable to the differences in the amount of soil and moisture delivered to the unloading station. When cutting with the cutter-transport and loading direct from the windrow, regardless of the soil-moisture classification, no significant differences in amounts of soil and moisture were found.

5. The use of the cutter-transport probably reduces the cost of hauling cane because of more net cane per load.

Effects of Field Damage:

1. The cutter-transport appears to do much less field damage than the V-cutter with rake-windrowing, particularly under wet operating conditions. The stool and soil and moisture data ob-

tained at Laupahoehoe are indexes which tend to verify this judgment. The effect of field damage on subsequent yields has not been determined.

2. The pickup-transport seems to do less field damage than the harvesting rake, loader and buggy. The information gathered by Pepeekeo, showing decreased plowing of areas scheduled for ratooning through use of the pickup-transport, bears out this judgment. The effect of field damage on subsequent yields has not been determined.

3. The Station Industrial Engineering Department concludes that the cutter-transport has considerable mobility under adverse soil-moisture conditions. General land slope is not a major factor, even under wet soil conditions, as the unit can be operated uphill across the cane lines.

TILLAGE

SOIL COMPACTION REDUCES CANE GROWTH

The effect of the 1958 strike is still evident in many cane fields due to (1) off-season harvesting of cane causing serious soil compaction during 1958 and 1959, and (2) inadequate reconditioning of infield roadways.

Following the strike, the pressing need for cane encouraged harvesting during climatic situations which normally would be considered unsuitable. During wet conditions, soils were compacted severely and to a greater depth than normal under harvesting traffic. Although the requirements for reconditioning of infield roadways were increased by the greater than normal state of compactness, pressures of getting the plantation back into full production often allowed too little time for adequate reconditioning operations.

Consequently, young fields showed evidence of restricted growth in the area of the infield roadways and these restrictions are continuing throughout the present crop (Figure 65). Normal development of replant in properly reconditioned roadways, although slower in starting, usually is characterized by growth rates identical to those in the rest of the field. In many of the ratoon fields investigated, over 15 per cent of the field showed reduced growth, about one-third of which was seriously set back. Even in fields which were tilled and newly planted, areas of restricted growth often comprised up to 5 per cent of the field, caused directly by soil compaction from previous harvest traffic.

Decisions on harvesting during questionable climatic situations should be based upon the availability of equipment for reconditioning operations,

Figure 65. Poorer growth of ratoon cane in roadways results from overcompaction from prior harvest and/or delayed replanting.

Table 27. Root Studies with Compacted Soils of the Kahana Family.

	Soil Density	
	Slight Damage Starts	Roots Fail to Grow
	lbs./cu. ft.	lbs./cu. ft.
Lihue Series:		
Surface	75	90
Subsoil	75	90
Koloa Series:		
Surface	75	98
Subsoil	75	98
Kilauea's Kahana:		
Surface	70	92
Subsoil	75	95

Table 28. Approximate Density Produced in Soils of Different Moisture Contents by Compaction at 85 lbs/in^2 (Truck Traffic).*

Soil Moisture	20%	22%	24%	26%	28%	30%
	(Density in pounds per cubic inch)					
Lihue Series:						
Surface	80	82	85	90	96	—
Subsoil	86	86	88	92	96	98
Koloa Series:						
Surface	88	91	95	98	—	—
Subsoil	83	85	97	93	98	—
Kilauea's Kahana:						
Surface	82	83	85	88	92	95
Subsoil	80	80	81	83	88	94

*Soils of the Kahana Family.

as well as the feasibility of being able to accomplish adequate reconditioning in terms of reduced future yields. Some soils compact more than others under adverse climatic conditions. In order to understand better how to handle our cane soils, work is continuing with a determination of the physical characteristics of cane soils. These studies include measurements of soil density in relation to root growth and in relation to the nature of field operations causing compaction. During the past year, studies within the soils of the Kahana family were stressed; these soil types are found on Kauai, Oahu, and Maui. In a generalized form, Tables 27 and 28 illustrate some of the preliminary results obtained.

TILLAGE REQUIREMENTS INVESTIGATED

The primary objectives of deep tillage are: (1) to extend the zone of effective root development, and (2) to facilitate furrowing and planting operations under furrow irrigation systems. The cost of deep tillage increases very rapidly with increasing tillage depths. The actual tillage depth required to meet the above objectives varies among soils. For example: the humic, humic ferruginous, and hydrol humic latosols allow deep rooting of cane irrespective of tillage depth (Figure 66). In contrast, on many low humic latosols and dark magnesium clays, roots are largely restricted to tillage depth (Figure 67).

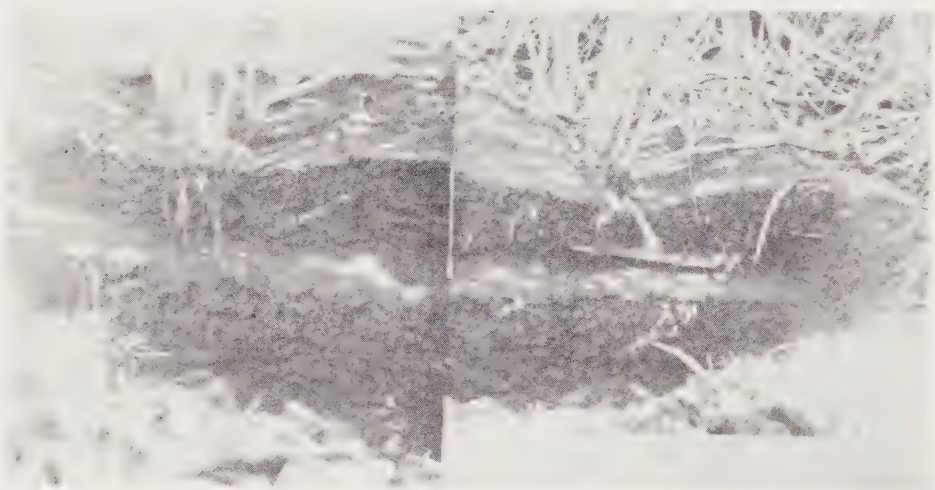


Figure 66. A hydrol humic latosol with cane roots penetrating and occupying soil below the depth of tillage.

Figure 67. A low humic latosol with cane rooting depth limited to tillage depth.

In the first example, considerations other than rooting depth must dictate the depth-of-tillage requirements. In the second example, the feasibility of increasing the depth of rooting by deeper tillage may depend on position of water table and on drainage conditions. It has been observed, however, that deep tilling enhanced root penetration in a dark magnesium clay where shallow water table was not a problem.

Of further practical interest on soils where deep tillage is beneficial to root development is the question of how long the beneficial effects of deep tillage on rooting persist. In areas deep-tilled eight years ago on two plantations, the present crop had developed roots throughout the deep-tilled zone. Whether the effects will persist throughout the whole cycle of present crop or extend beyond merits study under a wider range of conditions.

SOIL EROSION

A soil-erosion/water-infiltration study was instituted at Paauhau in cooperation with the Soil Conservation Service. Two runoff plots were established, equipped with drainage tubes and catchment basins. Also installed was a water stage recorder equipped with a float-actuated switch coupled to a rate-recording rain gauge. To date no storms have occurred with sufficient intensity to cause runoff.

Another phase of the same project entails applying water with a sub-boom on the Paauhau Ames Boom-O-Rain irrigation unit at rates higher than the soil intake rate and measuring soil removal. The first data from this study show 577 pounds per acre soil removed at an average application rate of 2.7 inches per hour. These tests will continue until meaningful results are obtained.

Figure 68. HSPA moldboard plow in operation, showing lowered hitchpoint of draft beam to cross beam.

MOLDBOARD PLOW MODIFIED

Development on this project has continued by (a) further experimentation on the HSPA-owned plow (Figure 68), (b) cooperative development on Oahu Sugar's plow, and (c) limited work on the plow owned by Hilo Sugar. Plowing depth has ranged from 14 to 24 inches. Additional patterns for the Teflon on the moldboards and methods of attaching the Teflon have been developed. To improve the draft condition, a new tool bar was designed and built. The attachment of the side draft beams to the crossbeam was dropped so that the side beams are approximately in the draft line from the tractor hitch point to the center of draft of the plow. This has been a factor in being able to keep the plow riding level with a range of plowing depths. A second factor has been to increase the suction of shares by bending the points down slightly if the plow tends to ride out.

The structural design based on the original HSPA plow has not been adequate for the irrigated plowing conditions. One 3-inch by 5-inch solid plow steel beam was successfully replaced with a 3-inch by 8-inch half-inch plate T_1 steel box section which has twice the strength with 25 per cent reduction in weight.

As a possible means of increasing plowing speed, Oahu Sugar dropped off the third bottom. The additional side draft on the tractor partially offset the effect of reduced draft. This emphasizes the necessity of the line of pull of the tractor being in line with the center line of draft of the plow, if possible.

The cooperative work with Hilo Sugar indicated the possibility of getting by without the use of Teflon. The combination of good tractor-power and lighter draft soils has made it possible to operate smoothly at a good plow speed.

Tool-bar corner-pivot brackets with hydraulic control have been made up for testing. This will provide a means whereby the operator can change the suction of the plow as he travels along and, also, as a first phase of lifting the plow out of the ground he can break the suction.

The recommended patterns for attaching Teflon on moldboard plows are shown in Figure 69. Teflon, Rulon and a new high-density polyethylene plastic from Union Carbide and Chemical Company have been investigated. The latter is cheaper in cost than the other two.

A NEW DESIGN FOR MOLDBOARD PLOW

The existing 32-inch plow bottom and moldboard shape were based on an estimate of what would do the job required for sugar cane. However, indications have been that a narrower cut may allow adequate depth of plowing. Also, a slower-speed moldboard shape may give a smoother plowed surface. Exploratory and development work

is planned on a single-bottom plow. Plow bottoms from manufacturers, recommended for adequate depths, will be used. Special design for width of cut and moldboard curvature will be made as required.

DRAFT AND STRESS TESTED IN PLOWING

The HSPA and Oahu Sugar three-bottom moldboard plows were used for a study of power requirements for tillage in one condition. The calibrated strain-gauge tension link was located in each draft beam of the tool bar assembly, and draft readings were recorded continuously on the Offner type D Dynograph assembly (Table 29).

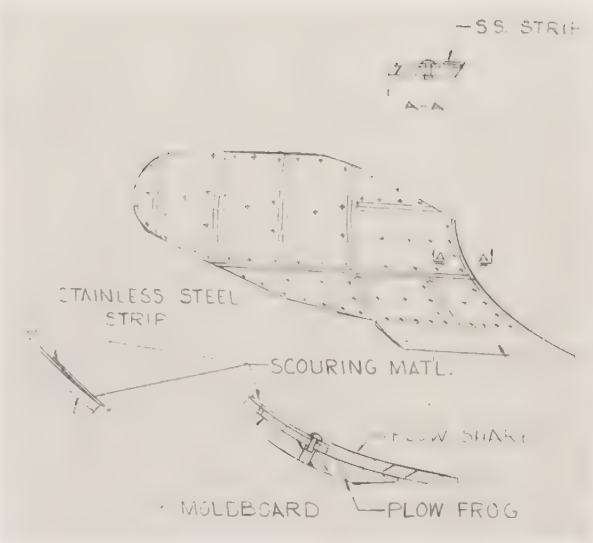


Figure 69. Recommended pattern and method of applying sheet Teflon to plow moldboard.

Table 29. Power Required for Tillage*

Plow		Total Draft (lbs.)	Unit Draft (lbs/in²)	Travel Speed (mph)	H.P. per in²	Total H.P. to Cut & Turn Soil
Oahu Sugar	—Peak	29,600	14.0	1.75	0.065	138
	—Mean	20,233	11.1	1.87	0.055	101
HSPA	—Peak	30,800	15.3	1.50	0.061	123
	—Mean	23,967	12.6	1.59	0.054	102

*In Kawai Hapai silty clay, moisture 34%, density 1.22.

VARIETIES

THE 1959–1960 CROSSING SEASON

The crossing season began on November 12, 1959, and ended on January 13, 1960. Tasseling was not exceptionally heavy, but generally good weather and the absence of destructive windstorms helped to make this crossing season an unusually successful one (Table 30).

Bi-parental crosses received a high priority in planning the program; 710 bi-parental crosses were set up, many representing combinations of highly desirable parents.

Table 30. Number of Crosses Undertaken During 1959–1960 Crossing Season.

General melting pot crosses	2,805
Leeward melting pot crosses	513
Windward melting pot crosses	341
Windward Mauka melting pot crosses	223
Q.R. melting pot crosses	232
Bi-parental crosses	710
Field crosses	112
1959–1960 Total	4,936
1958–1959 Total	4,386

PRELIMINARY SEEDLING TESTING

The regional network of 10 preliminary testing stations, together with the four 4-acre stations at HC&S, afford excellent facilities for carrying the annual populations of seedlings through the initial elimination stages (bunch, 5x4, and 5x14), all of which undergo selection at about one year of age.

The subsequent stage of testing, 30x24, is harvested for yield data at the normal age, which in the Kau uplands is three years but in most of the other districts is two years. Experience has shown that the 30x24 stage can be carried out more advantageously on the plantations than on the regional stations. Accordingly, this stage of testing has become a cooperative project under which the tests are installed in suitable areas provided by the plantations, the planting and harvesting operations being carried out by the Station task forces.

The 30x24 program is well under way on Kauai and Oahu and at HC&S. The recent establishment of a task force on Hawaii will permit the initiation of a 30x24 program on that island in 1961.

Table 31 lists the plantings in the preliminary testing program by regional stations and cooperating plantations.

VARIETY TESTING ON THE PLANTATIONS

The number of 10x20 and 10x25 tests show a decline from last year's total of 112 to 84 for the fiscal year. The 40x40 and 50x50 category shows a slight increase (Table 32).

The number of entries in replicated tests increased substantially on Hawaii, remained steady on Kauai, and decreased drastically on Oahu and Maui.

Details of seed distribution from the regional stations to the plantations are shown in Table 33.

CYTOLOGICAL INVESTIGATIONS

Cytological studies of wild and cultivated canes and their hybrid progeny have been continued by Dr. Sam Price. A report of his studies on the "Noble" canes (*Saccharum officinarum*) will appear in a forthcoming issue of the Planters' Record. Other reports have been published in botanical and cytological journals.

HARVESTING AND SUBSAMPLING OF FIELD PLOTS EXPEDITED

The initiation of task force harvesting on Hawaii under the supervision of O. H. Lyman and R. K. Conant has relieved some of the difficulties which have beset the harvesting of field experiments on that island.

A modification in the mounting of the Martin-Decker hydraulic remote-reading scale on the Waipio Quickway loader has overcome the difficulties initially encountered. The scale is now weighing with acceptable accuracy and with substantial man-hour savings over alternative weighing

Table 31. 1960 Preliminary Testing Plantings*

	No. of Flats	Number of Seedling Plots					
		Unnumbered 5x4	Numbered 5x4	5x14	10x20	30x24	40x40
Regional Stations							
Kailua Field Laboratory	2,805	2,415	1,095	—	—	—	—
Waipio Substation	1,454	16,280	6,579	1,450	—	353[a]	—
Helemano Variety Station	—	2,984	5,213	609	—	154[b]	—
Hilo Makai Variety Station	328	10,452	4,498	607	94	—	16
Hilo Mauka Variety Station	315	1,850	3,784	508	73	—	16
Hamakua Makai Var. Sta.	1,116	3,665	3,775	318	86	—	21
Hamakua Mauka Var. Sta.	225	1,397	1,913	564	62	—	22
Kohala Variety Station	—	3,922	1,987	243	51	—	14
Kau Variety Station	225	2,668	2,457	456	95	—	21
Lihue Variety Station	326	5,434	4,347	602	—	45[c]	—
McBryde Variety Station	706	5,268	3,682	786	—	150[d]	—
Plantations							
H.C.&S.Co.	—	3,520	5,869	1,221	—	269	—
Kohala Sugar Co.	—	—	1,951	141	—	9[f]	—
Honokaa Sugar Co.	—	—	993	—	—	—	—
Paauhau Sugar Co.	—	—	930	17	—	—	—
Hamakua Mill Co.	—	—	997	—	—	—	—
Hakalau Sugar Co.	—	—	667	—	—	—	—
Puna Sugar Co.	—	—	—	—	—	36[f]	—
Hawaiian Agr. Co.	—	—	1,080	—	—	—	—
Hutchinson Sugar Co.	—	—	1,769	110	—	—	—
Kilauea Sugar Company	—	—	—	157	—	—	—
Grove Farm Co.	—	—	1,941	185	—	24[e]	—
Kekaha Sugar Co.	—	—	—	253	—	38	—
1960 Total	7,500	59,855	55,527	8,227	461	1,078	110
1959 Total	6,777	59,531	47,074	9,256	385	752	115

*Breeding and spreading canes at Kailua Field Laboratory are not included in table. Plantation 10x20 and 40x40 plantings tabulated in Table 32.

**Number of seedlings per flat, 100-1,000.

Notes:

[a] Planted at Ewa, Kahuku, Oahu Sugar and Waialua.
[b] Planted at Kahuku and Oahu Sugar.
[c] Planted at Kilauea.
[d] Also planted at Olokele and McBryde Sugar Co.
[e] Sent from Lihue Plantation Co.
[f] 30x30 planting.

Table 32. Preliminary Tests Installed by Plantations (July 1, 1959 to June 30, 1960)

	Kauai	Oahu	Maui	Hawaii	Fiscal 1960 Total	Fiscal 1959 Total
10x20 and 10x25	21	11	5	47	84	112
40x40 and 50x50	26	12	7	48	93	86

Table 33. Seed Shipments to Plantations (July 1, 1959 to June 30, 1960)

Source	Tons for seed-nurseries	Number of plots for 10x20	Number of plots for 40x40
Kailua Field Laboratory	1.38	132	—
Waipio Substation	.40	1,476	—
Helemano Variety Station	—	18	—
Hilo Makai Variety Station	1.15	956	—
Hilo Mauka Variety Station	—	236	—
Hamakua Makai Variety Station	.80	1,216	—
Hamakua Mauka Variety Station	—	103	—
Lihue Variety Station	.58	89	—
McBryde Variety Station	5.98	127	8
Totals	10.29	4,353	8
Total 1958–1959	24.13	5,627	61

methods. This development has been carried out by F. C. Denison in cooperation with the Field Engineering Department.

Under Mr. Denison's supervision, the Waipio silage cutter has been mounted on wheels so that it can be towed directly to the harvesting field, obviating the time-consuming bundling and transporting of sample cane; the cost of sampling has been materially reduced by this development.

POL RATIO TECHNIQUES BEING EXPLORED

Interest in a disintegrator that can process samples larger than the 2-pound subsample accommodated by the present disintegrators led to the purchase of a 2-hp "Lightnin' Mixer" motor. This motor affords an adequate source of power which can operate continuously at full load without overheating; however, the motor has still to be equipped with an effective disintegrating tool.

The Physiology and Biochemistry Department has long employed a pol ratio procedure which involves expressing about 80 per cent of the juice in the sample at 1,000 psi. By determining Brix and pol of expressed juice and by drying the bagasse to determine its moisture content, fiber and pol per cent cane may be calculated. To explore the possibilities of this procedure when applied to larger samples, a 75-ton hydraulic press has been borrowed from the University of Hawaii. A cage large enough to accommodate a 4-pound subsample is being designed for fabrication by the Field Engineering Department. An evaluation of this approach will be undertaken when the cage is completed.

HEAT TREATMENT INCREASES 32-8560 YIELDS

In certain areas on Kauai and Hawaii, 32–8560 yielded well for several crops and then declined markedly in subsequent crops. On the other hand in some fields at Oahu Sugar and HC&S, 32–8560 continued to yield well over a long period.

To study the factors involved in the yield decline of 32-8560, the respective Island Representatives collected cuttings of 32-8560 from fields at Pepeekeo and Lihue which had shown pronounced yield decline and from fields at Oahu Sugar and HC&S which had maintained good yields over a number of crops.

These "good" and "poor" subclones of 32–8560 were planted for multiplication at Kailua. Subsequently half of the seed of each "poor" subclone was given a long-hot-water treatment (50° C for 2 hours), leaving the remaining half untreated. The three categories, "poor" untreated, "poor" LHWT, and "good" untreated, were planted in a seed nursery at Waipio. With seed from these sources a 30x24 plot of each subclone was planted in Waipio Field B. This test was harvested recently at 22 months of age with the following results:

	TPA
"Poor" subclones untreated Three plots (from Lihue, 2; from Pepeekeo, 1)	12.3
"Poor" subclones, LHWT Three plots (same original sources as above)	16.2
"Good" subclones untreated Six plots (from Oahu Sugar, 3; from HC&S, 3)	14.1

The yield response of the "poor" subclones to the long-hot-water treatment suggests that the initial impairment of their yielding ability was due, in part at least, to a systemic pathogen such as ratoon stunting disease which the long-hot-water treatment eliminated.

This evidence points to the usefulness of LHWT nurseries as a means of forestalling yield decline that might otherwise result from the uncontrolled spread of systemic pathogens such as chlorotic streak and ratoon stunting disease.

ROOT ROT—THE MAJOR CAUSE OF YIELD DECLINE

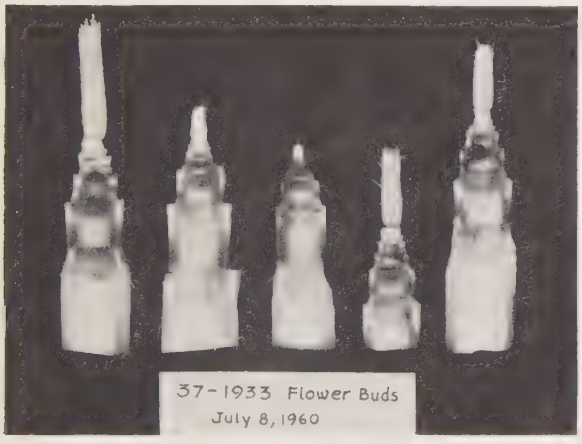
Experimental studies by the Pathology Department have shown that *Pythium* root rot is a principal factor in the failure of commercial varieties to maintain original yields. In some areas nematode injury to roots is causing reduced cane growth. The sugar cane root-rot fungus, *Pythium graminicolum*, played a major part in the failure of Lahaina from 1895 to 1924 and has been associated as a contributing factor in growth failure areas since that time. The fungus, being an active soil parasite, invades the roots and causes them to rot. The root hairs and fine rootlets are highly susceptible to attack and are readily injured not only by soil organisms (*Pythium* sp. and nematodes) but also by poor aeration, waterlogging, soil com-

paction, toxic chemicals, and lack of soil moisture.

Apparently the only practical solution to the problem at the moment is the use of newer varieties.

RAIN DOES NOT CHANGE CMU TASSEL CONTROL

A test last year showed that the tassel-controlling effect of CMU spray was not altered by 1 acre-inch of rain applied nine hours after spraying. Table 34 shows the results of a similar test to determine the effects of variations in the amount of rain and the time after spraying. The spray was applied at the rate of 5 pounds of 80 per cent CMU per acre; data were obtained for 0.5 acre-inch and for 1 acre-inch of rain at 2, 4, 6, and 8 hours after spraying. The table shows that CMU once sprayed on cane foliage is effective in plants subjected to heavy rain a very short time afterward. One acre-inch of rain two hours after the CMU spray did not prevent reasonably good tassel control.



SUGAR CANE TASSELS CONTROLLED AND INDUCED

Dr. Robert E. Coleman returned to the Station to replace Dr. Graham Davis as USDA representative on the collaborative work on flowering. The following results of Dr. Davis' work are of special interest:

1. Night lighting begun on September 11 completely inhibited flowering of 37–1933, whereas 29 of 30 plants flowered in the unlighted control plots.

2. Maleic hydrazide was far less effective than CMU in controlling flowering (33 per cent vs. 100 per cent). DCMU and CMU were the only chemicals tested that gave satisfactory control.

3. Removal of the spindle in September prevented flowering (90 per cent control).

Dr. Coleman soon had a number of plants of 37–1933 marcotted and flower buds induced for crossing with early flowering varieties. This was done in the spring in the photoperiod houses at 70° to 80° F. for 60 days, the day length being 12.5 hours. Figure 70 shows the development of five flowers as of July 8 in 37–1933, a variety that normally forms flower initials about September 10 to 15.

Figure 70. Flowering induced two months early.

Table 34. Effect of Rain on CMU Spray to Control Tasseling

Treatment	Percentage No-Tassel Stalks		
	Rain		No rain
	0.5 acre-inch	1.0 acre-inch	(Check plots)
Sprayed check No. 1			96
Sprayed check No. 2			100
Rain 2 hrs. after spray	76	68	
Rain 4 hrs. after spray	84	88	
Rain 6 hrs. after spray	96	80	
Rain 8 hrs. after spray*	80	40	
3 no-spray checks			0

*Varying figures for 8-hr plots due to clogged nozzles during spraying.

WEED CONTROL

SCREENING AND STATUS OF NEW HERBICIDE CHEMICALS

An exceptional number of new potential herbicide chemicals were received and processed during the year. This reflects: (1) an increased ability to screen large numbers of chemicals by fairly rapid laboratory methods; (2) increased contacts with Mainland firms interested in evaluation of their products under local conditions; and (3) a closer cooperation with the Pineapple Research Institute which has resulted in a number of new materials, principally growth and flowering regulators. A brief summary of those compounds warranting further study is given in Table 35. The triazines are discussed separately.

TRIAZINES (SIMAZINE AND RELATED PRODUCTS)

New triazines continue to come to us from the Geigy Agricultural Company. At present, Simazine, Atrazine, Atratone, Prometone, Simetone, and Ipazine show the most promise as chemicals for use prior to germination of weed seed, although all but Simazine show post-germination activity in some degree. The new products listed in Table 36 are said to possess more contact activity. All are wettable powders except Atrametryne, which is a 25 per cent emulsifiable concentrate. The name Ipatone has been assigned to the triazine previously reported as G-31717.

NEW FORMULATIONS OF PENTACHLOROPHENOL FOR PREGERMINANT WEED SEED CONTROL

Osamine (triethylamine salt of pentachlorophenol).

This new formulation of pentachlorophenol (OSA), which carried 5 pounds of OSA per gallon as a liquid concentrate, was developed to fill the need for a more concentrated solution which could be dissolved either in oil or water, and which would permit rates of application of 25 to 100 pounds of OSA per acre by plane or in irrigation water without involving large volumes of diluent.

The value of pentachlorophenol as a pregerminate "seedicide" makes it very likely that the use of this cheap and important chemical will continue to increase. A number of formulations as the free phenol, the sodium salt, and the amine salt are now available for a wide variety of conditions.

Osacon (emulsifiable concentrate of pentachlorophenol in oil).

This concentrate continues to get increased use and testing as a formulation for the application of pentachlorophenol as a pregerminant seedicide.

HORMONE FORMULATION UTILIZES FREE ACIDS

Dr. F. E. Hance, retired Principal Chemist, reports the development of a new formulation of plant hormones and selected pre-emergence compounds. The hormonal formulation with such chemicals as 2,4-D, 2,4,5-T, and Silvex, utilizes the free acid forms for economy, low volatility, and maximum activity. The "solvent" imparts particularly interesting penetrating properties, increasing the hormonal and systemic action. Details will be released in Station publications as testing is carried out.

ACTIVITIES OF PRE-EMERGENCE HERBICIDES LINKED TO SOIL ADSORPTION

Most chemicals, whether fertilizers or herbicides, applied to soil are in some degree fixed or adsorbed to active sites. There are three types of bonding forces holding the chemicals to soil sites: (1) cation exchange in which hydrogen or some other easily replaceable positive ion is exchanged, as is the case when ammonium, potassium, calcium, or other metal salts are added to the soil; (2) anion exchange in which hydroxyl ion or other negative ion is replaced by an anion such as phosphate, sulfate, or chloride; and (3) nonionic physical adsorption involving no direct ionic exchange.

Fixation of herbicides, or their adsorption on soil, is almost entirely of two types: (1) the anion exchange in which negative ions of herbicide acids, such as pentachlorophenol, 2,4-D, Silvex, Dalapon, trichloroacetic, and chloric (chlorates), are fixed on active exchange sites in much the same way that phosphate ion is fixed; (2) pre-emergence

Table 35. Performance of Chemical Herbicides

Name	Herbicide Action	Performance
Pentachlorobenzenethiol (PCBT)	Contact	Not equal to OSA
Urox and Urab	Pre-emergence	Equivalent to a combination of STCA and CMU or Fenuron
Fluorine Analogs of 2,4-D	Hormone on grasses and broad leaves	Higher cost compared with selective 2,4-D
Delapon Ester (Kenapon)	Systemic	Apparent better penetration in grasses than sodium dalapon
Zytron (M-1329)	Pre-emergence	Looks good on grasses in basic tests
Dacthal (DAC-893)	Pre-emergence	Disappointing
Dupont 685	Pre-emergence	No longer available
Reglone (FB-2)	Contact and systemic also a plant desiccant	Non-selective, but active against 2,4-D resistant species
Tetrachlorophenol, alone or mixed with pentachlorophenol	Contact	Pentachlorophenol superior
Dodecylbenzene sulfonic acid (DDBSA) with PMU, CMU, DCMU	Pre-emergence	This inexpensive oil-soluble emulsifier offers attractive possibilities
4-Nitro, 3-trifluoromethylphenol	Contact	Effective but cannot compete costwise with pentachlorophenol
Ethyl o-nitrophenyl sulfide (Monsanto CP-13842)	Soil sterilant	More effect on grasses than broad leaves
Monsanto CP-17029	Pre-emergence	Resembles triazines—inadequately tested as yet

Table 36. New Triazines Released in 1960

	Substituent on Position		
Name	2	4	6
Atrametryne	ethylamino	isopropylamino	methylthio
Simetryne	ethylamino	ethylamino	methylthio
G-34360	isopropylamino	methylamino	methylthio
Prometryne	isopropylamino	isopropylamino	methylthio
G-34696	chloro	ethylamino	3-methoxypropylamino
G-34698	chloro	isopropylamino	3-methoxypropylamino

herbicides (CMU, DCMU, Simazine, Atrazine and the like) do not exist in solution as ions and cannot be considered as fixed in the ionic sense; for these materials the adsorption is dependent only on surface properties or "surface activity" and thus is analogous to the removal of impurities by bone char in sugar refining or to adsorption chromatography on activated carbon and activated clays.

Soil adsorption of the pre-emergence herbicides such as CMU, DCMU, and Simazine removes a portion of the chemical from soil solution where it would otherwise be available to the roots of weed seedlings or cane. The rate of solution of the chemical will be dependent on available soil moisture and the intrinsic water solubility of the chemical. A weakly adsorbing soil will allow more vertical leaching to take place (assuming sufficient moisture) and thus more of the chemical will reach the cane root level, while a tightly adsorbing soil will keep most of the chemical near the surface

away from the cane root zone. This latter case is more desirable, assuming the adsorption does not remove such a large part of the available chemical that weed control is poor.

The method of establishing base levels of soil adsorption consists of preparing a standardized aqueous solution of the chemical, shaking a 50 g. portion of the soil with 100 ml. of the solution, filtering the aqueous portion, and reanalyzing the residual herbicide concentration in the filtrate, either by direct chemical analysis or by counting of radioactive samples.

The following conclusions can be drawn from the work so far completed:

1. Extensive variability exists among Hawaiian soils in adsorption of pre-emergence chemicals.
2. The same general trend of adsorption for DCMU and Simazine is noted as for CMU, although Simazine shows numerous exceptions. DCMU adsorption is greater than that of CMU in all cases.
3. Simazine shows greater departure from CMU values than does DCMU and, in general, higher adsorption in soils for which CMU values are low.
4. The adsorption of the pre-emergence herbicides is a surface property dependent on the nature of the chemical and on the organic content and clay fraction of the soil.
5. In general, gray hydromorphic and dark magnesium clays and the hydrol humic latosols show high adsorptive capacity while the low humic latosols, Kahana family but not Molokai family, and the humic ferruginous soils are relatively low.
6. Subsoils are generally very low in adsorptive capacity and are often deficient in plant food nutrients.

BASIC TESTING PROCEDURES PERMIT CLOSER SCREENING OF HERBICIDES AND OTHER CHEMICALS

The Chemistry Department expects to set up laboratory testing procedures to evaluate the phytotoxic properties of any chemical which may be obtained from a manufacturer or prepared in our laboratories. The importance of using the proper chemical at the proper stage in the development of the weed plant needs special emphasis. Contact action chemicals are most active in penetrating weed seed coats and in destroying the embryo plant. Other materials, mainly systemics, show marked activity only in the immediate post-germination or hypocotyl stage, while others are active only in differentiating plant tissue when nutrients are being used from soil solution. Thus, the pre-emergence chemicals are active only in this third stage of growth and are relatively inactive against seed and small seedlings.

The contact value of numerous chemicals has been evaluated against ungerminated seed. Radish and Sudan grass seed were used because they give highly reproducible results and are easy to germinate. A material which is toxic in this test reflects the value of a pesticide as a contact herbicide and also the degree of "burn" which might be expected from pre-emergence chemicals applied over crops. Furthermore, a chemical which is especially effective in inhibiting germination of seed is an obvious candidate to be considered for treatment of irrigation ditches since the amount of weed seed introduced this way is considerable. This test also indicates selectivity of a chemical for grass and broad-leaved varieties. Special weed-seed collections are being made, and special problems will be treated separately.

Of the more than 200 chemicals tested, only eight rated particularly high in the basic contact test, while an additional 49 had considerable seed contact effect. Selection was made on the basis of the following classification:

Class	Kill of Radish or Sudan Seed	Concentration of Chemical
	%	ppm
A	at least 50	4.7
B	at least 50	9.4
C	at least 75	over 18.9, under 150
D	at least 90	over 300, under 600
E	complete kill	over 1,200, under 2,400
F	less than 100	2,400

TESTING OF SPROUTED SEEDS INDICATES VALUE OF MANY SYSTEMIC HERBICIDES

Although the ungerminated seed may be considered an embryonic plant, a chemical which is inactive or only slightly active at this stage could mean that the seed can detoxify the chemical applied, or that the enzyme systems sensitive to certain herbicides are not yet present. Hence, the systemic test involves the application of herbicides to young plants after seed germination. While only a few chemicals have been examined so far, the method is as rapid as that for the contact herbicides. It is easy to differentiate chemicals active against monocotyledenous weeds from those active

on dicotyledenous plants. Initial trials indicate that 3-aminotriazole, isopropyl-n-(3-chlorophenyl) carbamate (CIPC), Eptam, and the hormonal herbicides are particularly toxic to plants at this early stage of growth. The pre-emergence chemicals evaluated so far are not toxic in this test, apparently indicating that they have no action until the plant tissue differentiates and active photosynthesis and nutrient uptake has begun. Many chemicals are growth stimulators at levels below the toxicity dosage. The stimulation can be accurately measured as a function of the amount of chemical applied; it is possible that some crop growth advantage can be gained from the proper use of such chemicals. It was found that CIPC, previously tried and rejected as a pre-emergence herbicide because of fairly rapid inactivation in the soil at our temperatures, is especially active as a post-germination treatment on grass seedlings.

The value of the pre-emergence chemicals has not been shown in either of these tests. Screening will require plants at a more advanced growth state planted in soil under controlled conditions. The use of Lemna, a small aquatic plant complete with roots and leaves, has shown promise as a laboratory method of observing growth under controlled conditions of light and temperature.

SIMAZINE AND PENTACHLOROPHENOL LEAVE NO RESIDUES IN PLANTS

The analytical methods for detection of residues of Simazine and Atrazine in cane have been continually improved. Since cane contains an enzyme system capable of metabolizing Simazine (and probably other triazines as well), trace residues have been found only for a few weeks after application of relatively high levels of the chemical.

The analytical method has been worked out for detection of pentachlorophenol residues that may occur in cane, molasses, and raw sugar. Samples of mill products so far examined show no traces of pentachlorophenol.

HERBICIDES TESTED ON PLANTATIONS

The following number of cooperative herbicide observations tests were conducted on plantations: Hawaii, 55; Kauai, 29; Maui, 5; Oahu, 63. Of the triazine compounds, Simazine has been cleared for use in sugar cane at 4 pounds per acre active material applied before cane emergence. Second application clearance is pending.

Other triazine compounds showing promise are: Atrazine, Atratone, Prometone, Ipatone, and Ipazine; however, none of these are cleared for use in sugar cane. OSA and WSA showed good results as pre-emergence chemicals, above 20 pounds per acre, and have also been applied in irrigation water to control weeds in the cane line. There has been little, if any, effect on cane up to 1000 pounds OSA per acre applied pre-emergence. Dalapon ester has shown results better than the sodium salt in some areas in the control of manienie, especially on strains tolerant of dalapon; it is not cleared for use in sugar cane and it is not yet available commercially.

Yield tests were harvested at HC&S Field 310, where dalapon had been applied at 5 pounds per acre, with 0, 10, 50, and 100 per cent coverage of the cane plants, plus a check treatment which received no dalapon, and in Field 718 where from ¼ to 8 pounds per acre were applied over plants of varieties 37–1933 and 38–2915. The results indicated no significant difference in yield between treatments.

A test procedure has been developed for obtaining yields of green cane at approximately eight months in order to determine the effects of herbicides on sugar cane.

HERBICIDES HAVE DIFFERENT EFFECTS ON CANE VARIETIES

Eight of the leading commercial sugar cane varieties, 37–1933, 39–7028, 39–5803, 44–3098, 49–5, 49–104, 49–3533, and 50–7209, were treated with eight herbicides, 2,4-D sodium salt, 2,4-D triethanolamine salt, 2,4-D PGBE ester, CMU, DCMU, Simazine, dalapon, and TCA. Gradings were made on germination and cane effect after 5 pounds per acre both as pre-emergence herbicide application and as an application when cane plants were 15 to 20 inches tall, repeated when the cane was 30 to 36 inches tall. All varieties showed slight to severe reduction in germination where either form of 2,4-D or TCA was applied directly to exposed seed pieces. Dalapon affected some varieties. There was no apparent deleterious effect on germination from either CMU, DCMU or Simazine over exposed seed.

In the normal pre-emergence application, only a few cases of reduced germination resulted from the different forms of 2,4-D. All other chemicals

resulted in no appreciable difference in germination from that of the check treatments.

Applied over the plant, the ester forms of 2,4-D caused most damage to all varieties, sodium salt the least. CMU caused more damage than DCMU to most varieties, with variety 50–7209 showing no effect from either and variety 39–5803 being the most affected by DCMU. There was no apparent effect on any variety from Simazine. Dalapon showed more effect than TCA when applied once at 5 pounds per acre over cane.

STRAINS OF BERMUDA GRASS VARY IN HERBICIDE TOLERANCE

Twenty strains of Bermuda grass (*Cynodon dactylon* L. pers.) were collected from Kauai, Oahu, and Hawaii at random, except that the Kilauea and Honokaa herbicide-tolerant strains from previous tests were included, as well as the Makiki strain as a check (Figures 71 and 72). Specimens were chosen to show variation in leaf type and growth characteristics. Each strain was planted in pots at Makiki and was treated with dalapon at 5 pounds per acre and with TCA at 20 pounds per acre; the check received no treatment. Gradings were made periodically and pots were retreated as needed at the original level of herbicide. Results are shown in Table 37.

Although several strains are similar in appearance and were collected from similar locations, they show variability in tolerance to chemicals. This may explain why a chemical may be effective on one plantation but ineffective on a neighboring plantation.

Table 37. Herbicide Tolerance of Bermuda Grass

Strain	Dalapon	TCA
Honokaa #1	Highly tolerant	Highly tolerant
Kilauea #2	Highly tolerant	Highly tolerant
Kekaha #2 (coast Bermuda grass)	Highly tolerant	Highly tolerant
Kohala #1	Highly tolerant	Highly tolerant
Hamakua #1	Highly tolerant	Highly tolerant
Uganda (fine-leaved lawn grass)	Highly tolerant	Highly tolerant
Kekaha #4	Susceptible	Highly susceptible
Kilauea #1	Susceptible	Tolerant
Ewa #1	Susceptible	Tolerant
Hilo #1	Susceptible	Tolerant
Laupahoehoe #1	Susceptible	Tolerant
Makiki #1	Susceptible	Susceptible
Kekaha #1	Susceptible	Susceptible
Kekaha #3	Highly susceptible	Highly susceptible
Lihue #1	Susceptible	Susceptible
Wailua #1	Highly susceptible	Highly susceptible
Ewa #2	Highly susceptible	Highly susceptible
Mokuleia #1	Susceptible	Susceptible
Paauhau #1	Susceptible	Susceptible
Honokaa #2	Susceptible	Susceptible

HERBICIDE APPLICATOR TESTED IN IRRIGATED FIELDS

This all-wheel-drive unit, equipped with Terra-Tires, has been operated at five plantations on Hawaii. The operation included spot, interline, broadcast, and stroller spraying. The machine was recently set up to spray four interlines with ground-speed metering of the spray material for operation on Kauai. After the Kauai operation, it is scheduled to be shipped to Maui.

Operation in unirrigated, flat culture fields has been satisfactory. Increased stability was attained by lowering the center of weight and lengthening the wheel-base. The center of weight was lowered by locating the spray supply tank below the frame. After these changes were made, the travel up and down and across slopes up to 35 per cent was satisfactory.

Operation in irrigated areas has been satisfactory. This unit can travel on the ridges or in the furrows. Damage to the fields in crossing lines is negligible. This machine can be set up for six-row broadcast, four-row interline, two-row spot spray, or four strollers. Estimates of production can be based on the following:

1. Unirrigated cane, plant or ratoon, travel speed, 2.5 to 5 mph, depending on the condition of the field and the terrain. Turning speed was 2.5 mph.

2. Irrigated cane, plant or ratoon, travel speed on ridges was 1.25 to 1.5 mph. Travel in the furrows, 2.5 to 3 mph. Turning speed, 1.25 mph.

3. Spot spray with the operator taking two centers, 1 mph.

4. Four-man stroller, ground speed 1 mph.

Concrete flumes can be crossed by placing wooden blocks in the flume to keep the weight of the machine from being carried by the walls of the flume.

The general observation of the operation of this machine has always indicated the desirability of such a unit being a two-way machine. This would reduce the turn-around time at the ends and increase the comfort of the operator, particularly in surface-irrigated areas where, in lines 135 to 200 feet in length, one-half to three-fifths of the operating time is required to turn the vehicle at flumes and roadways. Some planning has been

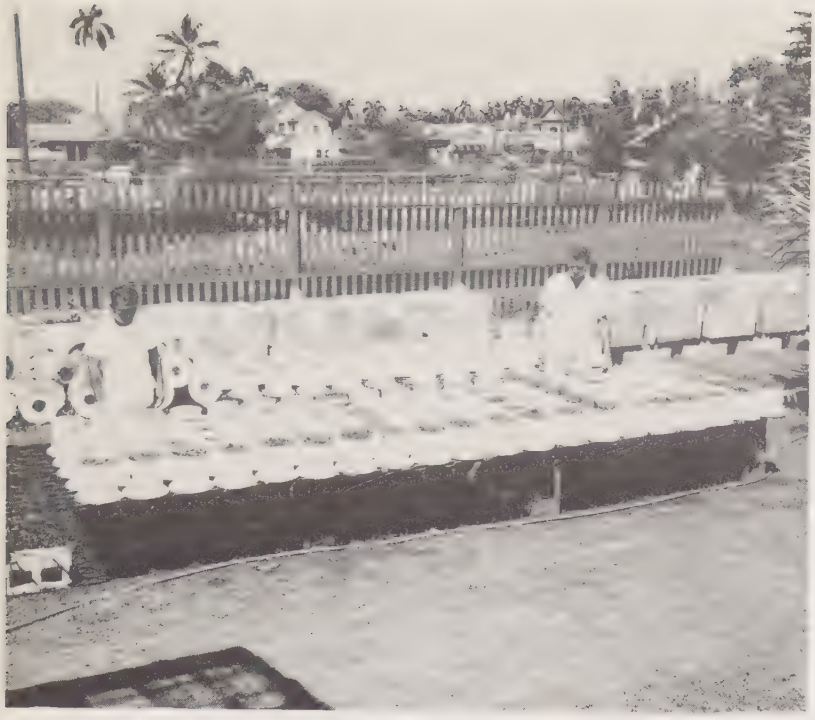


Figure 71. Pots of Bermuda grass for herbicide tolerance tests.

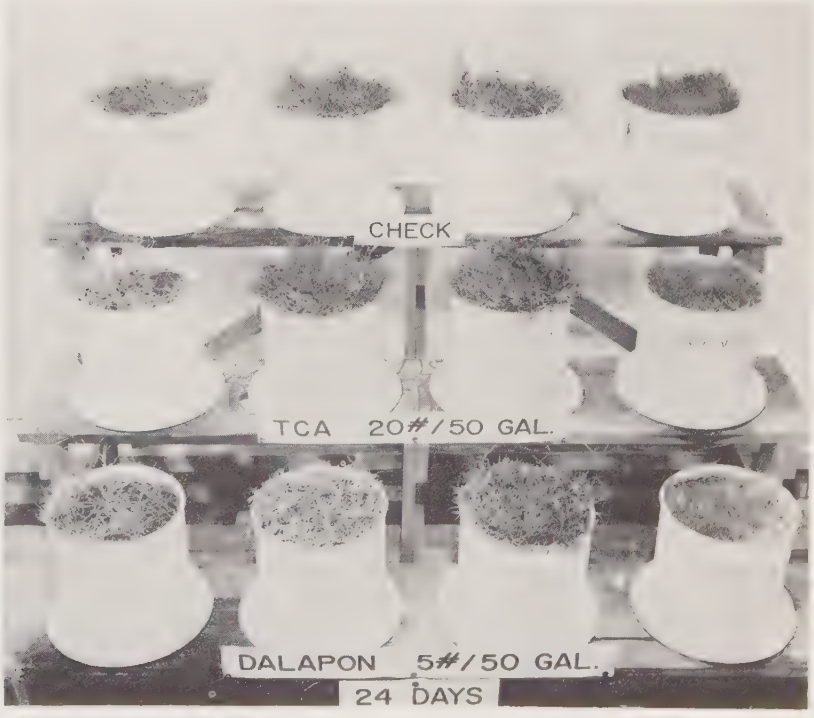


Figure 72. Four strains of manienie, including Uganda grass, show varying tolerance to Dalapon and TCA.

done relative to converting this unit to a two-way, back-and-forth operation. The estimated additional machine cost can be weighed against the estimated production increase.

The performance of this machine has been satisfactory and the Terra-Tires have given satisfactory traction and mobility over a wide range of field conditions. The major problem which must be resolved is the economics of this special-built machine as compared with getting along with a standard prime mover. One point established by this machine is that, in addition to having low-pressure tires with good traction, all wheels must be powered.

The results with this unit to date indicate that a redesign of this type of unit to take out all costs possible would approach a minimum unit from the standpoint of adequate performance and maneuverability for a practical range of field, terrain, and weather conditions.

2, 4-D SPRAY DRIFT STUDIED IN WIND TUNNEL

A wind tunnel has been set up at the Waipio Substation to study 2,4-D spray drift under controlled conditions. The tunnel consists of a series of transite pipes, 20 inches in diameter, laid end to end for a total length of 130 feet (Figure 73). A fan at one end blows air through at a maximum velocity of 16 to 18 mph, which decreases to 10 to 12 mph at the far end; a spray box, with observation windows on both sides, is located near the fan for herbicide application.

Tests have been run with 2,4-D amine containing a fluorescein dye; indicators of drift, all placed at various distances from the spray nozzle, have been tomato plants, petri dishes for lettuce seed germination, and white cards. Pressures of 30 psi and 3 psi were used to test four nozzles: 11008 Tee Jet, T. G. 3.5 solid cone, HSPA sprinkler, and K-10 flooding nozzle.

Figure 73. Wind tunnel for studying spray drift and spray pattern.

Nozzle delivery in all cases was adequate for plantation field practice. Under low pressure (3 psi), all four nozzles cut spray drift down to less than 50 feet; under high pressure (30 psi), 2,4-D effect was great the entire 130 feet (Figures 74 and 75). The test is being conducted with the cooperation of the State Department of Agriculture and Conservation.

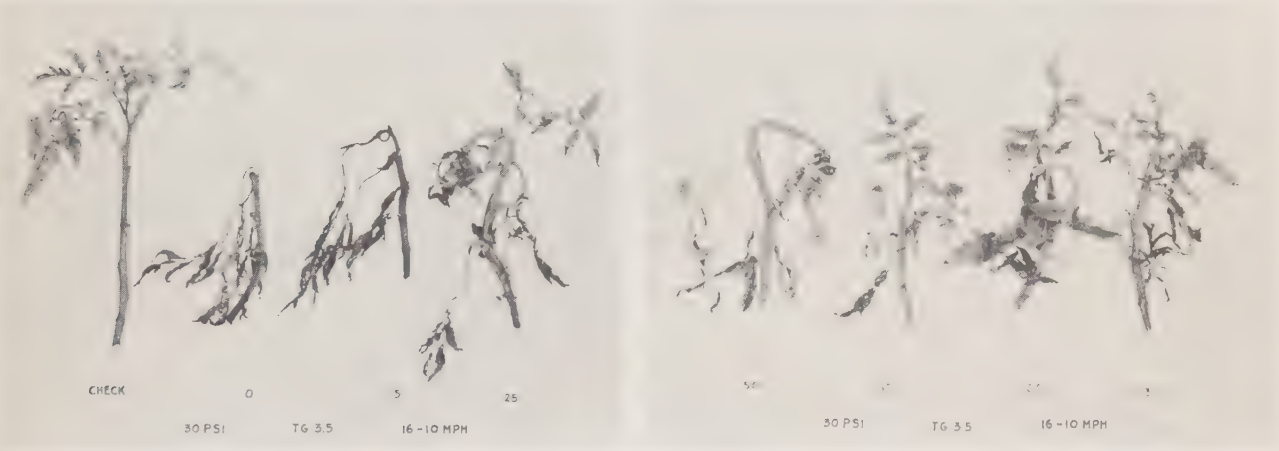


Figure 74. Tomatoes sprayed in wind tunnel with 2, 4-D (5 lbs/50 gals) at high pressure. Except for the check, the plants were exposed in the wind tunnel at 0, 15, 25, 50, 65, 105, and 130 feet from T.G. 3.5 soil-cone nozzle at 30 psi in air velocity varying from 16 mph near the fan to 10 mph at the far end. The spray patterns on cards indicated that there were many droplets so small that they would be little affected by gravity. Consequently as the water evaporated, the active principle could be carried long distances by air currents.

Figure 75. Tomatoes sprayed in wind tunnel with 2, 4-D at low pressure. Compare these results with those shown in Fig. 74. These plants, except the check, were exposed in the wind tunnel at the indicated distances in feet from a T.G. 3.5 solid-cone nozzle operated at 3 psi. Air velocity was 10-16 mph. Note only slight symptoms on plants from 15 to 50 feet. The plant at 0 feet got direct spray from the nozzle. There were no symptoms of 2, 4-D beyond 50 feet. The spray patterns showed all droplets to be larger than 50 microns, a size greatly affected by gravity, hence the short distance of drift.

APPLYING HERBICIDES IN IRRIGATION WATER

Because of the variability in water distribution found in most irrigation systems, and the resultant chemical damage to cane, it has not been possible to use irrigation water for applying such herbicides as 2,4-D and related compounds, the substituted ureas, triazines or the grass killers, dalapon and TCA.

Tests with OSA and some with WSA now indicate that because of the high tolerance of sugar cane to these herbicides, it is possible to apply these chlorinated phenols in irrigation water.

Levels of OSA and WSA at 25 and 50 pounds per acre have given control about equal to 4 pounds per acre of CMU, DCMU and Simazine in the wetted portion of the irrigation furrow. Tests at Waipio have shown that application of 2 and 4 pounds of OSA per acre in repeated irrigations, up to a total of 13 rounds, has kept the wetted furrows completely free of weeds with no damage to 37–1933.

OSA or WSA can be applied with the same equipment used for applying liquid fertilizers in irrigation water. OSA should be applied as the ARCADE Concentrate (ARCON) formula since this emulsion disperses uniformly through the water. WSA can be applied as a concentrate in water since it is water soluble.

In general, OSA applied as a spray has been more successful for control of the weed species found in irrigated fields than those found in unirrigated fields in higher rainfall areas.

NEW IDEAS IN HERBIDICE EQUIPMENT

1. Fiberglass Knapsacks (Figure 76). Pressure knapsacks fabricated from glass fiber imbedded in polyester resin show promise, both from the standpoint of weight reduction and reduced cost. This unit incorporates a pressure tank built of glass fiber and polyester resin. Otherwise, it is constructed similarly to the stainless steel tanks presently in use in the Hawaiian sugar industry. Its main value is in possible reduction in cost in comparison with the stainless steel. Matters relative to safety of operation, as related to testing and repair, are still pending.

2. Spray Blowers (Figure 77). Small knapsack-mounted engines and blowers have been developed to apply herbicides, either as low-gallonage, highly concentrated sprays or as dusts or granules. These continue to be tested for use in sugar cane. Tests indicate that herbicides can be applied as an air stream instead of as diluted sprays.

Figure 76. Fiberglass pressure knapsack.

This unit, built in Germany but available on the local market, incorporates a small two-cycle engine that drives a fan for providing an air stream. The concentrated liquid or dust is dispersed into the air stream for application. At low motor-speed, the spray droplets are uniform in size and large enough to prevent serious spray drift; at high motor-speed, the spray can be atomized.

3. Double-nozzle Spray Gun (Figure 78). A double-nozzle spray gun with double-action valve was developed at HC&S. Partial pressure on the handle opens one nozzle to sweep-spray small weeds; full pressure opens both nozzles to spray large weeds. This accomplishes the spraying rapidly and prevents the slowing down of the sprayman's walking pace.

Figure 77. Spray blower for applying concentrate.

Figure 78. Double-nozzle spray gun with double-action valve.

4. Roadside Spray Boom on Jeep Unit (Figure 79). A short spray boom with 4 tee-jet nozzles on the boom, and an adjustable TOC nozzle at the end for close and wide spraying, was developed for use on a jeep sprayer at Lihue Plantation. This type of over-all roadside unit has the pump run off the power take-off and has inside-the-cab controls for one-man operation. It should be built on a 2-ton jeep truck instead of a 1-ton unit, in which case a 500-gallon tank could replace the present 300-gallon tank. The truck can have an adjustable governor mounted for controlling motor speed and consequent over-the-road speed; this makes close calibration of application possible.

Figure 79. Roadside spray boom on Jeep sprayer. Note the four tee-jet nozzles on the boom and the swinging TOC nozzle at the end of the boom.

Figure 80. Assistants-in-Training for Agriculture: Lawson Wylie, Mead Kirkpatrick, Donald Cataluna, Malcolm McPhail, Myron O. Isherwood, Jr. Insert: Daniel F. Jones.

Figure 81. Plantation Enrollees for Short Court in Agriculture: Robert Ota (Hawaii Extension Service), Richard Isaacs (Wailuku Sugar Co.), Hisao Kaya (Onomea Sugar Co.).

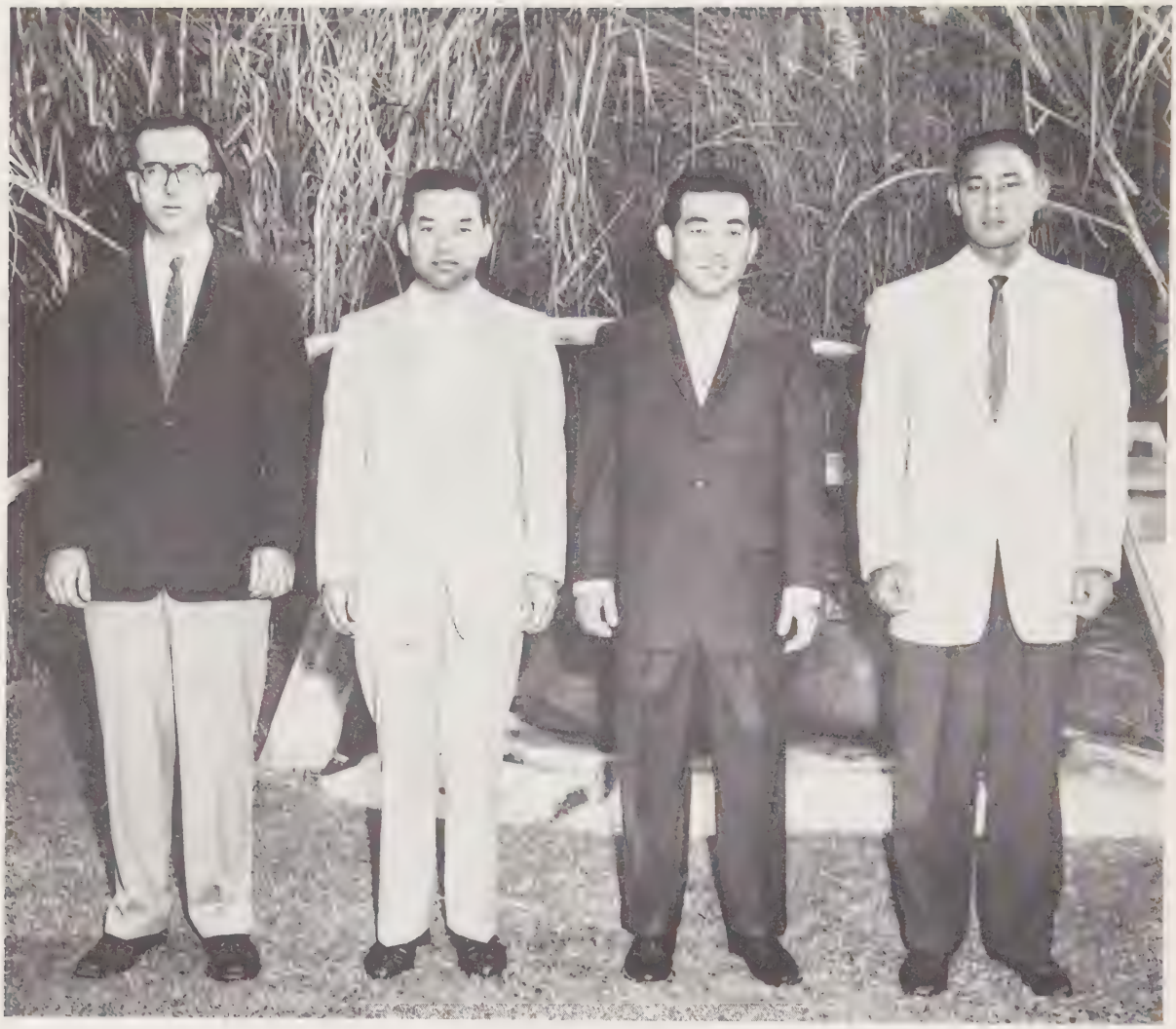


Figure 82. Assistants-in-training, Sugar Technology: .Richard M. Belt, Kenji Nishioka, Harry Muranaka, Andrew Padilla, Jr.

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September 30, 1960

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F. A. Bianchi — *Principal Entomologist*
J. W. Beardsley, Jr. — *Associate Entomologist*
W. R. Smythe — *Assistant Entomologist*
J. S. Rosa — *Technical Assistant*

EXPERIMENTAL STATISTICS

J. G. Darroch — *Principal Statistician*
R. K. Tanaka — *Assistant Statistician*
Harriet C. Suzuki — *Statistics Technical Assistant*

MOLOKAI QUARANTINE STATION

George Otsuka ..... *Field Laboratory Superintendent*

FIELD ENGINEERING

R. A. Duncan ..... *Chief Engineer*

E. R. Bolles ..... *Senior Design Engineer*
W. P. Burton ..... *Project Engineer*
W. E. Hart ..... *Project Engineer*
C. B. Holtwick ..... *Project Engineer*
T. Adachi ..... *Design Engineer*
L. H. Anderson ..... *Test Engineer*
S. Kawamura ..... *Design Engineer*
S. Matsuoka ..... *Design Engineer*
E. M. Norum ..... *Assistant Project Engineer*
G. S. Palmerton ..... *Assistant Design Engineer*
T. R. Uyechi ..... *Assistant Design Engineer*
J. M. Feiteira, Jr. ..... *Assistant Design Engineer*
J. H. S. Kim, Jr. ..... *Assistant Design Engineer*
Y. Isa ..... *Shop Foreman*

GENETICS

A. J. Mangelsdorf ..... *Principal Geneticist*

J. N. Warner ..... *Senior Geneticist*
Sam Price ..... *Associate Geneticist (Coop. USDA)*
R. Urata ..... *Associate Geneticist*
D. W. Davis ..... *Assistant Geneticist*
A. Doi ..... *Assistant Geneticist*
H. Terayama ..... *Assistant Geneticist*
R. Chi ..... *Senior Genetics Assistant*
N. Kimura ..... *Senior Genetics Assistant*
K. Nishimoto ..... *Senior Genetics Assistant*
M. Tanaka ..... *Field Laboratory Superintendent*

INDUSTRIAL ENGINEERING

Warren Gibson ..... *Principal Industrial Engineer*

D. J. Dougherty ..... *Senior Industrial Engineer*
R. B. Arakaki ..... *Assistant Industrial Engineer*

PATHOLOGY

J. P. Martin ..... *Principal Pathologist*

C. A. Wismer ..... *Senior Pathologist*
H. Koike ..... *Associate Pathologist*
A. S. Miura ..... *Senior Laboratory Assistant*

PHYSIOLOGY AND BIOCHEMISTRY

G. O. Burr ..... *Principal Physiologist and Biochemist*

H. W. Brodie ..... *Senior Physiologist*
Constance E. Hartt ..... *Senior Physiologist*
H. P. Kortschak ..... *Senior Biochemist*
T. Tanimoto ..... *Associate Biochemist*
R. B. Coleman ..... *Assistant Physiologist (Coop. USDA)*
Ada Forbes ..... *Assistant Physiologist*
David Takahashi ..... *Assistant Biochemist*
R. S. Yoshida ..... *Technical Assistant*

SUGAR TECHNOLOGY

J. H. Payne ..... *Principal Technologist*

G. E. Sloane ..... *Senior Technologist*
Chen-Chaun Tu ..... *Senior Technologist*
R. K. Hamilton ..... *Associate Technologist*
Toshio Moritsugu ..... *Associate Technologist*
L. J. Rhodes ..... *Associate Technologist*
F. J. Dupin ..... *Scale Inspector*
K. M. Onna ..... *Assistant Technologist*
H. S. Iwata ..... *Technical Assistant*

WEED CONTROL RESEARCH

N. S. Hanson ..... *Principal Scientist in Charge*
R. D. Wiemer ..... *Assistant Scientist*

PERSONNEL TRAINING

N. S. Hanson ..... *Principal Coordinator*

STATION PERSONNEL CHANGES

JOINED THE STAFF

L. H. Anderson	*Test Engineer*	Field Engineering
R. K. Conant	*Supervisor, Hawaii Task Force*	Island Representative—Hawaii
D. J. Dougherty	*Senior Industrial Engineer*	Administration
Edith L. Haselwood	*Associate Editor*	Administration
J. R. Higgins	*Engineering Assistant*	Field Engineering
George Stanford	*Principal Agronomist*	Agronomy
R. E. Temple	*Assistant Chemist*	Chemistry
R. D. Wiemer	*Assistant Scientist*	Weed Control Research
R. S. Yoshida	*Technical Assistant*	Physiology & Biochemistry

LEFT THE STAFF

H. Agena	*Senior Technical Assistant*	Physiology & Biochemistry
G. W. Aljian	*Coordinator*	By-Products
D. C. Cox	*Principal Geophysicist*	Geophysics
J. R. Higgins	*Engineering Assistant*	Field Engineering
R. P. Humbert	*Principal Agronomist*	Agronomy
W. H. Kahl	*Project Engineer*	Field Engineering
S. B. Knapp	*Senior Pulp and Paper Technologist*	By-Products
T. Yamamoto	*Assistant Chemist*	Chemistry

RETIRED

W. P. Alexander	*Principal Coordinator*	Personnel Training
Lydia C. Nickerson	*Associate Editor*	Administration